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JOURNAL of PALEONTOLOGY

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JOURNAL OF PALEONTOLOGY, VOL. 5, NO. 4, PP. 297-315, PLS. 34-36,
DECEMBER, 1931

THE FORAMINIFERA OF THE SARATOGA CHALK[1]

JOSEPH A. CUSHMAN
Sharon, Massachusetts

ABSTRACT

The foraminifera of the Saratoga chalk from the type locality show very close relationships with the Upper Cretaceous chalk species of Europe and also of the Upper Cretaceous of other parts of America. The vertical ranges are very variable, some species being of short range while the range of others is comparatively long. The accompanying paper describes these various species and gives a discussion of their ranges.

The foraminiferal faunas of the various chalks of the American Upper Cretaceous present an interesting problem. It is to be suspected that the ecologic conditions under which the chalks were deposited had a marked effect upon the distribution of genera and species. For this reason the correlation of the different chalks with their time equivalents in the clays, marls, and sands is somewhat difficult and complex. Before the definite correlation problems can be well worked out it is very necessary to know the elements of the faunas very much in detail. To supply this need and give illustrations of the various species a series of papers is planned on the Upper Cretaceous chalks. Through the kindness and coöperation of Messrs. Thomas and Rice excellent collections have been made from the type localities and turned over to the writer for description and illustration. Only the descriptions of the fauna will be given by the writer, and a discussion of the chalks left to Messrs. Thomas and Rice who have had a wide experience with these as they occur in well drillings and surface outcrops.

As other papers are being prepared on the various formations of the Upper Cretaceous of Texas and adjoining regions no detailed ranges of distribution of these species are given here although general notes are given as to their geographic distribution in the Up-

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per Cretaceous. A discussion of the species in the accompanying paper, however, gives some of the vertical distributions as shown by well samples of Texas. The problem of the vertical distribution of the species of the chalks is a somewhat complex one, and will be elaborated as other members of the Upper Cretaceous are described in detail.

As noted previously in discussions of the Upper Cretaceous faunas of America, the species of Europe and America are for the most part identical. Nearly all of the foraminifera of the Saratoga chalk have already been described from European Upper Cretaceous chalk facies.

In order to make this paper as short as possible full descriptions are given only of those species which have not already had adequate descriptions in the later American literature. References to the original publication and to recent American papers are given for ease in reference.

All the specimens figured are from outcrop material from the type locality, Saratoga, Arkansas.

DESCRIPTION OF SPECIES

FAMILY LITUOLIDAE

GENUS FLABELLAMMINA CUSHMAN, 1928

FLABELLAMMINA SARATOGAENSIS CUSHMAN, N. SP.

Plate 34, figures 1*a*, *b*

Test much compressed, periphery rounded, early portion close coiled and involute, later adult chambers uncoiled and the axis becoming straight; chambers fairly distinct, especially those of the later portion, increasing very slightly in size as added; sutures fairly distinct, only slightly depressed; wall coarsely arenaceous, composed of large grains of various sorts firmly cemented and with a fairly smooth surface; aperture elongate, elliptical, terminal. Length of holotype 1.25 mm.; breadth 0.95 mm.; thickness 0.35 mm.

Holotype (Cushman Coll. No. 15592) from the Upper Cretaceous Saratoga chalk, Saratoga, Arkansas.

FAMILY TEXTULARIIDAE

SUBFAMILY SPIROPLECTAMMININAE

GENUS SPIROPLECTAMMINA CUSHMAN, 1927

SPIROPLECTAMMINA ANCEPS (REUSS)

Plate 34, figures *2a, b*

Textularia anceps Reuss, *1845-46*, Verstein. böhm. Kreide, pt. 1, p. 39, pl. 8, fig. 79; pl. 13, fig. 78; *1860*, Sitz. Akad. Wiss. Wien, vol. 40, p. 234, pl. 13, figs. *2a, b*.—Egger, *1899*, Abhandl. kön. bay. Akad. Wiss. München, Cl. 11, vol. 21, p. 25, pl. 24, figs. 35, 36.

Spiroplectammina anceps Cushman and Church, *1929*, Proc. Calif. Acad. Sci., ser. 4, vol. 18, p. 500, pl. 36, figs. 1, 2.—Cushman, *1931*, Bull. 41, Tenn. Geol. Survey, p. 18, pl. 1 figs. *5a, b*.

Textularia sagittula var. *coonensis* W. Berry, *1929*, in Berry and Kelley, Proc. U. S. Nat. Mus., vol. 76, art. 19, p. 3, pl. 2, fig. 3.

This is a fairly common species of the Upper Cretaceous of Europe and America, having been already recorded from the Cretaceous of California and Tennessee. There is considerable variation in the coiled early portion, many more chambers being present in the microspheric than in the megalospheric, but the coiled chambers are usually visible in all specimens.

FAMILY VERNEUILINIDAE

GENUS GAUDRYINA D'ORBIGNY, 1836

GAUDRYINA CHAPMANI FRANKE

Plate 34, figures *3a, b*

Gaudryina chapmani Franke, *1928*, Abhandl. Preuss. Geol. Landes., n. ser., vol. 111, p. 146, pl. 13, figs. *12a, b*.

Test elongate, tapering, slightly fusiform, the sides for a considerable part of the test nearly parallel in the biserial portion, very slightly compressed; early chambers triserial, indistinct, later ones biserial, slightly inflated, of rather uniform size and shape; sutures fairly distinct and slightly depressed in the biserial portion forming an angle of about 30° with the horizontal; wall roughened, rather coarsely arenaceous; aperture at the inner margin of the last-formed chamber in a distinct re-entrant. Length of figured specimen 1.70 mm.; breadth 0.45 mm.; thickness 0.30 mm.

This species has already been described by Dr. Franke from the Cretaceous of Pomerania, Germany. Our specimens from the Saratoga chalk seem to be identical with the European ones.

GAUDRYINA OXYCONA Reuss
Plate 34, figures 4*a*, *b*

Gaudryina oxycona Reuss, *1860*, Sitz. Akad. Wiss. Wien, vol. 40, p. 229, pl. 12, figs. 3*a-c*; *1862 (1863)*, vol. 46, p. 33.—Franke, *1925*, Abhandl. geol. pal. Instit. Univ. Greifswald, vol. 6, p. 15, pl. 1, figs. 20*a*, *b*.—Cushman and Church, *1929*, Proc. Calif. Acad. Sci., ser. 4, vol. 18, p. 501, pl. 36, figs. 3, 4.

This is one of the very widely distributed species of the Upper Cretaceous originally described from Germany. It has already been recorded from the California Cretaceous, and occurs in the Gulf Coastal Plain region of the United States, the Velasco shale of Mexico and in the Upper Cretaceous of Trinidad. It may be easily distinguished by its conical shape and nearly circular end view.

EXPLANATION OF PLATE 34

FIGS. 1*a*, *b*—*Flabellammina saratogaensis* Cushman, n. sp. × 25. *a*, Front view; *b*, Apertural view. (p. 298)

2*a*, *b*—*Spiroplectammina anceps* (Reuss), × 40. *a*, Front view; *b*, Apertural view. (p. 299)

3*a*, *b*—*Gaudryina chapmani* Franke, × 30. *a*, Front view; *b*, Apertural view. (p. 299)

4*a*, *b*—*Gaudryina oxycona* Reuss, × 40. *a*, Front view; *b*, Apertural view. (p. 300)

5*a*, *b*—*Gaudryina minima* Egger, × 40. *a*, Front view; *b*, Apertural view. (p. 301)

6, 7*a*, *b*—*Gaudryina pupoides* d'Orbigny, × 40. 7*a*, Front view; *b*, Apertural view. (p. 301)

8*a*, *b*—*Heterostomella foveolata* (Marsson), × 40. *a*, Front view; *b*, Apertural view. (p. 301)

9*a*, *b*—*Clavulina amorpha* Cushman, × 30. *a*, Front view; *b*, Apertural view. (p. 302)

10, 11*a*, *b*—*Clavulina trilatera* Cushman, × 30. 10, Megalospheric form. 11, Microspheric form; *a*, Side view; *b*, Apertural view. (p. 302)

12*a*, *b*—*Clavulina trilatera* Cushman, var. *concava* Cushman, n. var., × 25. *a*, Side view; *b*, Apertural view. (p. 302)

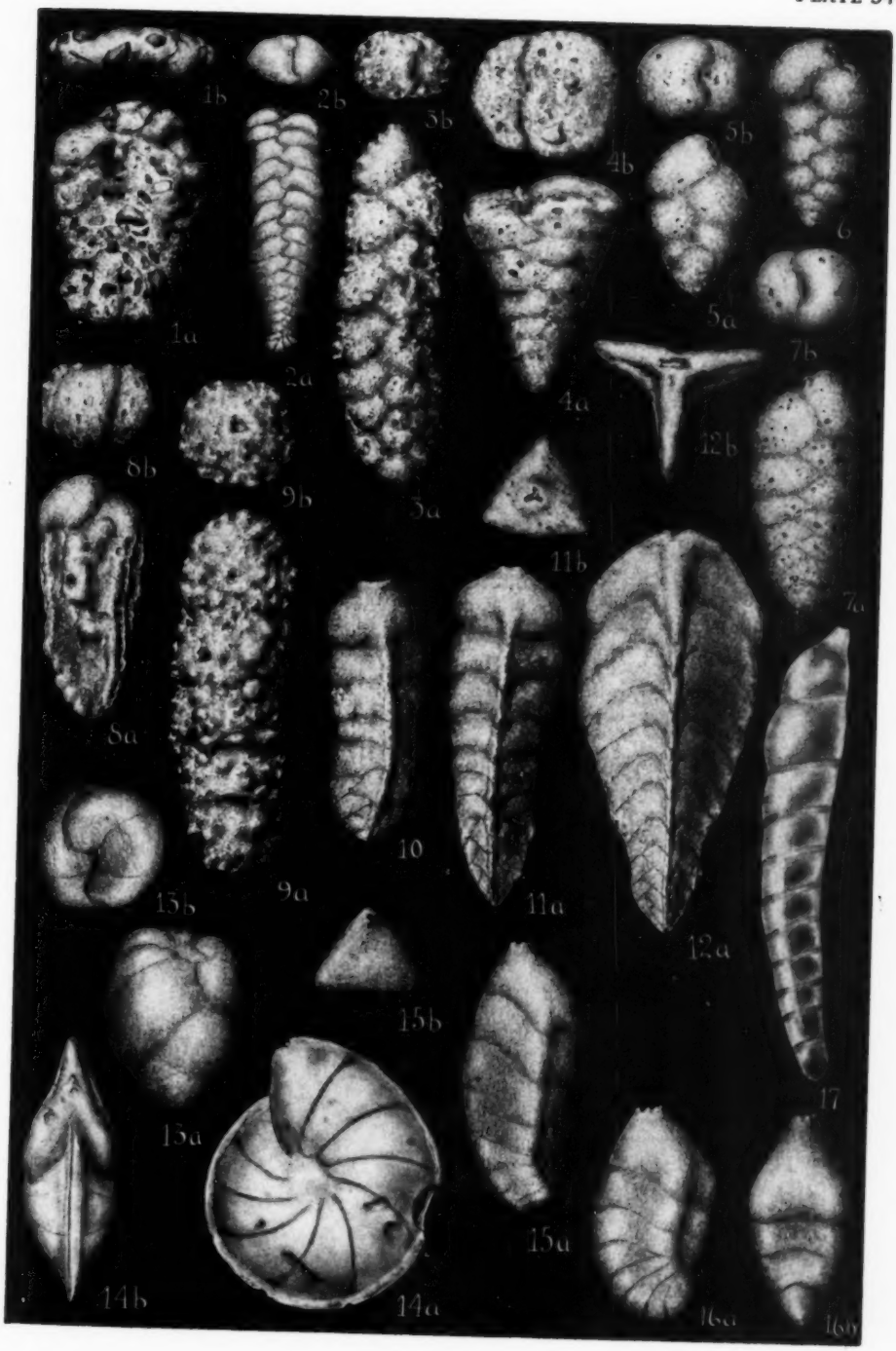
13*a*, *b*—*Arenobulimina presli* (Reuss), × 40. *a*, Front view; *b*, Apertural view. (p. 303)

14*a*, *b*—*Robulus navarroensis* (Plummer), × 25. *a*, Side view; *b*, Peripheral view. (p. 305)

15*a*, *b*, 16*a*, *b*—*Saracenaria italica* Defrance, × 20. 15*a*, Side view; *b*, Apertural view. 16*a*, Side view; *b*, Front view.

17—*Dentalina megalopolitana* Reuss, × 40. (p. 304)

Figures drawn by Margaret S. Moore



Cushman, Cretaceous Foraminifera

GAUDRYINA MINIMA Egger
Plate 34 figures 5*a*, *b*

Gaudryina minima Egger, *1899*, Abhandl. kön. bay. Akad. Wiss. München, Cl. II, vol. 21, p. 37, pl. 24, fig. 26.

Test small, somewhat compressed, periphery rounded, tapering from the initial end to the greatest breadth formed by the last two chambers; chambers few, those of the triserial portion indistinct, the adult biserial portion usually made up of two or three pairs of chambers; sutures of the early portion indistinct, in the biserial portion somewhat depressed making an angle of about 20° with the horizontal; aperture semicircular, at the base of the inner margin of the last-formed chamber. Length of figured specimen 0.60 mm.; breadth 0.40 mm.; thickness 0.30 mm.

This species described from the Cretaceous of Bavaria by Egger occurs widely distributed in the Upper Cretaceous of America. It may be distinguished by the small size and relatively few chambers in the biserial portion with the rather high semicircular aperture.

GAUDRYINA PUPOIDES d'Orbigny
Plate 34, figures 6, 7

Gaudryina pupoides d'Orbigny, *1840*, Mém. Soc. Géol. France, sér. 1, vol. 4, p. 44, pl. 4, figs. 22-24.

D'Orbigny originally described this species from the Upper Cretaceous chalks of the Paris Basin at Meudon, etc. A study of French Cretaceous chalk specimens seems to show that the figured specimen given by d'Orbigny is not entirely a normal specimen, although the general arrangement of the chambers and appearance can be found in almost any large series of specimens. The biserial portion is composed of somewhat inflated chambers, and the sutures are very nearly horizontal. Such specimens are rather common in the upper portion of the American Upper Cretaceous, and should probably be referred to d'Orbigny's species.

Genus HETEROSTOMELLA Reuss, 1865

HETEROSTOMELLA FOVEOLATA (Marsson)
Plate 34, figures 8*a*, *b*

Tritaxia foveolata Marsson, *1878*, Mitth. nat. Ver. Neu-Vorpommern und Rügen, Jahrg. 10, p. 161, pl. 3, figs. 30*a-c*.—Franke, *1925*, Abhandl. geol. pal. Instit. Univ. Greifswald, vol. 6, p. 19, pl. 2, fig. 3.
Heterostomella foveolata Cushman, *1928*, Contr. Cushman Lab. Foram. Res., vol. 4, p. 111, pl. 16, figs. 9-12.

This species is widely distributed in the Upper Cretaceous chalks known from various localities in Germany and England, as well as occurring abundantly in the chalks of Texas. It has numerous longitudinal rows of irregular openings resulting from the breaking down of the fistulose projections of the longitudinal ridges which mark this species.

Genus CLAVULINA d'Orbigny, 1826

CLAVULINA AMORPHA Cushman

Plate 34, figures 9*a*, *b*

Clavulina amorpha Cushman, *1926,* Bull. Am. Assn. Petroleum Geol., vol. 10, p. 589, pl. 17, fig. 5.—White, *1928,* Jour. Pal., vol. 2, p. 315, pl. 42, fig. 12.—Cushman and Jarvis, *1928,* Contr. Cushman Lab. Foram. Res., vol. 4, p. 93, pl. 13, fig. 9.—Cushman, *1931,* Bull. 41, Tenn. Geol. Survey, p. 21, pl. 1, figs. 12, 13.

Reophax cylindricus H. B. Brady, var. *ripleyensis* W. Berry, *1929,* in Berry and Kelley, Proc. U. S. Nat. Mus., vol. 76, art. 19, p. 2, pl. 1, fig. 5.

Reophax coonensis W. Berry, *1929,* l.c., p. 2, pl. 3, fig. 23.

This species is known from various localities in the Upper Cretaceous of America, occurring in the Velasco shale of Mexico, in the Upper Cretaceous of Trinidad, and the upper portion of the Cretaceous of Tennessee. It is also fairly well distributed in the Upper Cretaceous of the general Gulf Coastal Plain region.

CLAVULINA TRILATERA Cushman

Plate 34, figures 10, 11

Clavulina trilatera Cushman, *1926,* Bull. Am. Assn. Petroleum Geol., vol. 10, p. 588, pl. 17, fig. 2; *1927,* Jour. Pal., vol. 1, p. 149, pl. 28, fig. 1.—White, *1928,* l.c., vol. 2, p. 315, pl. 42, fig. 13.—Cushman and Jarvis, *1928,* Contr. Cushman Lab. Foram. Res., vol. 4, p. 93, pl. 13, fig. 8.—Morrison, *1929,* Bull. Am. Assn. Petroleum Geol., vol. 13, p. 1,066 (list).—Cushman, *1931,* Bull. 41, Tenn. Geol. Survey, p. 22, pl. 2, figs. 1-3.

This is an abundant form in the Upper Cretaceous of Mexico, Trinidad, and the Coastal Plain region of the United States. It is somewhat variable in form, especially in the microspheric and megalospheric forms, the former being much more elongate and tapering, while the latter is smaller and has the sides nearly parallel for most of the length.

CLAVULINA TRILATERA Cushman, var. CONCAVA Cushman, n. var.

Plate 34, figures 12*a*, *b*

Variety differing from the typical in the larger size and the much extended angles giving the concave appearance to at least two of the three sides. Length of holotype 2.30 mm.; diameter 1.00 mm.

Holotype of variety (Cushman Coll. No. 15601) from the Upper Cretaceous of the Saratoga chalk, Saratoga, Arkansas.

This large form found with the typical, especially in the Coastal Plain region of the United States, seems to be varietally distinct. It may be distinguished by its large size, and very distinctly wing-like projections with deeply concave sides.

Family VALVULINIDAE

Genus ARENOBULIMINA Cushman, 1927

ARENOBULIMINA PRESLI (Reuss)

Plate 34, figures 13*a*, *b*

Bulimina presli Reuss, *1845-46*, Verstein. Böhm. Kreide, pt. 1, p. 38, pl. 13, fig. 72.
Arenobulimina presli Cushman, *1927*, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 4, p. 80; *1928*, Special Publ. No. 1, Cushman Lab. Foram. Res., pl. 12, figs. 17*a*, *b*; pl. 13, fig. 21.

Test spiral, nearly circular in end view, in the early portion consisting of three chambers to a whorl, in the adult with as many as five; sutures fairly distinct, slightly depressed; wall finely arenaceous, smoothly finished; aperture a semicircular indentation at the base of the last-formed chamber near the middle of the apertural end in a generally depressed area. Length of figured specimen 0.70 mm.; diameter 0.50 mm.

There are numerous records for this species in the Upper Cretaceous of Europe, and while it does not seem to occur as abundantly in America, nevertheless it is found in the Saratoga chalk and probably in other portions of the Upper Cretaceous of the general Gulf Coastal Plain region.

Family LAGENIDAE

Genus ROBULUS Montfort, 1808

ROBULUS NAVARROENSIS (Plummer)

Plate 34, figures 14*a*, *b*

Cristellaria navarroensis Plummer, *1926 (1927)*, Univ. Texas Bull. 2644, p. 39, figs. 4*a*, *b* (in text).
Robulus navarroensis Cushman, *1931*, Bull. 41, Tenn. Geol. Survey, p. 25, pl. 2, figs. 8*a*, *b*.
Cristellaria midwayensis W. Berry (not Plummer), *1929*, in Berry and Kelley, Proc. U. S. Nat. Mus., vol. 76, art. 19, p. 7, pl. 1, fig. 3.
Cristellaria orbicularis d'Orbigny, var. *minuta* W. Berry, l.c., p. 8, pl. 1, fig. 2.

This species described by Mrs. Plummer from the Navarro formation of Texas is rather widely distributed in the Upper Cretaceous

of the Gulf Coastal Plain region. It occurs in the Navarro formation of Texas very abundantly, and both in the Coon Creek and Selma chalk faunas of Tennessee.

Genus MARGINULINA d'Orbigny, 1826

MARGINULINA ELONGATA d'Orbigny

Plate 35, figures 6*a*, *b*

Marginulina elongata d'Orbigny, *1840,* Mém. Soc. Géol. France, sér. 1, vol. 4, p. 17, pl. 1, figs. 20-22.—Reuss, *1845-46,* Verstein. Böhm. Kreide, pt. 1, p. 129, pl. 13, figs. 28-32; pt. 2, p. 107, pl. 24, figs. 31-36.—Franke, *1925,* Abhandl. geol. pal. Instit. Univ. Greifswald, vol. 6, p. 54, pl. 4, fig. 23; *1928,* Abhandl. Preuss. Geol. Landes., vol. 111, p. 76, pl. 7, fig. 5.—Cushman and Church, *1929,* Proc. Calif. Acad. Sci., ser. 4, vol. 18, p. 506, pl. 38, figs. 1-3.—Cushman, *1931,* Bull. 41, Tenn. Geol. Survey, p. 26, pl. 2, figs. 10*a*, *b*.

This species has already been recorded from the Upper Cretaceous, Selma chalk of Tennessee. It is widely distributed in the Upper Cretaceous of both Europe and America. The last-formed chambers are thin walled, and are usually broken away as is the case in the figured specimen.

Genus DENTALINA d'Orbigny, 1826

DENTALINA MEGALOPOLITANA Reuss

Plate 34, figure 17

Dentalina megalopolitana Reuss, *1855,* Zeitschr. deutsch. geol. Ges., vol. 7, p. 267, pl. 8, fig. 10.—Cushman, *1931,* Bull. 41, Tenn. Geol. Survey, p. 29, pl. 3, fig. 8.

Nodosaria megalopolitana Franke, *1925,* Abhandl. Geol. Pal. Instit. Univ. Greifswald, vol. 6, p. 33, pl. 3, fig. 8.—Cushman, *1926,* Bull. Am. Assn. Petroleum Geol., vol. 10, p. 595, pl. 18, fig. 16.

This is a rather common and distinctive species of the Upper Cretaceous of both Europe and America. Our figured specimen is somewhat more slender than many of the specimens found. Frequently the middle portion is considerably inflated.

DENTALINA CONFLUENS Reuss

Plate 35, figure 1

Dentalina confluens Reuss, *1861 (1862),* Sitz. Akad. Wiss. Wien, vol. 44, pt. 1, p. 335, pl. 7, fig. 5.

Test elongate, slightly tapering, the early portion often somewhat compressed; later chambers becoming inflated and distinct; sutures depressed, especially in the later portion; wall ornamented by nu-

merous rather coarse longitudinal costae, those of the early portion particularly, continuous over adjacent chambers and often somewhat oblique, later ones often broken at the sutures; aperture at the end of a distinct neck, radiate. Length 2.00-2.80 mm.; diameter 0.50-0.60 mm.

This is a large form with the sutures oblique. The ornamentation consists of rather obliquely arranged, fine, longitudinal costae. It shows considerable variation in any large series. It was originally described from the Upper Cretaceous of Germany, and occurs in the Upper Cretaceous of Trinidad, as well as in the Coastal Plain region of the United States.

Genus NODOSARIA Lamarck, 1812

NODOSARIA AFFINIS Reuss

Plate 35, figures 2-5

Nodosaria affinis Reuss, *1845-46,* Verstein. Böhm. Kreide, pt. 1, p. 26, pl. 13, fig. 16; *1874,* in Geinitz, Palaeontographica, vol. 20, pt. 2, p. 83, pl. 20, fig. 12. —Franke, *1925,* Abhandl. Geol. Pal. Instit. Univ. Greifswald, vol. 6, p. 37, pl. 3, fig. 25.—Berry and Kelley, *1929,* Proc. U. S. Nat. Mus., vol. 76, art. 19, p. 6, pl. 1, fig. 8.—Cushman, *1931,* Bull. 41, Tenn. Geol. Survey, p. 30, pl. 3, figs. 16-20.

Nodosaria proxima Berry and Kelley (not Silvestri), *1929,* Proc. U. S. Nat. Mus., vol. 76, art. 19, p. 7, pl. 1, fig. 13.

This is one of the most common species in the Upper Cretaceous of America and Europe. There is a great deal of variation in the different forms, the microspheric forms being very distinctly tapering and enlarging from the initial end throughout growth, while in the megalospheric forms the proloculum is often as large as any of the following chambers or in extreme forms may be much larger than any of the succeeding ones. In some specimens with a very large proloculum only two chambers are developed. Such a series has already been figured from the Upper Cretaceous of Tennessee, and several figures are given here from the Saratoga chalk.

Genus SARACENARIA Defrance, 1824

SARACENARIA ITALICA Defrance

Plate 34, figures 15, 16

Saracenaria italica Defrance, *1824,* Dict. Sci. Nat., vol. 32, p. 177; *1827,* vol. 47, p. 344; Atlas, Conch., pl. 13, fig. 6.

Our Cretaceous specimens seem to be so close to the form described by Defrance that it is impossible to separate them at the pres-

ent time. This species is widely distributed in the late Cretaceous, Tertiary, and Recent collections.

Genus VAGINULINA d'Orbigny, 1826

VAGINULINA SIMONDSI Carsey

Plate 35, figure 7

Vaginulina simondsi Carsey, *1926*, Univ. Texas Bull. 2612, p. 40, pl. 2, fig. 4.—Cushman, *1930*, Contr. Cushman Lab. Foram. Res., vol. 6, p. 27, pl. 4, figs. 6-8; *1931*, Bull. 41, Tenn. Geol. Survey, p. 33, pl. 4, figs. 7, 8.

The single broken specimen figured here may perhaps not belong to this species, but has many characters in common with it. The species is evidently a variable one, and is already known from Texas, Arkansas, and Tennessee.

EXPLANATION OF PLATE 35

Figs. 1—*Dentalina confluens* Reuss, × 40. (p. 304)

2-5—*Nodosaria affinis* Reuss, × 25. *2*, *3*, Megalospheric forms. *4*, Microspheric form. *5*, Extreme megalospheric form. (p. 305)

6*a*, *b*—*Marginulina elongata* d'Orbigny, × 40. *a*, Side view; *b*, Apertural view. (p. 304)

7—*Vaginulina simondsi* Carsey, × 25. (p. 306)

8—*Frondicularia cordai* Reuss, × 25. (p. 307)

9—*Flabellina interpuntata* von der Marck, × 40. (p. 307)

10—*Flabellina rugosa* d'Orbigny, × 25. (p. 307)

11—*Lagena vulgaris* Williamson, × 40. (p. 308)

12—*Lagena acuticosta* Reuss, × 75. (p. 308)

13*a*, *b*—*Bolivinoides decorata* (Jones), var. *delicatula* Cushman, × 40. *a*, Front view; *b*, Apertural view. (p. 308)

14*a*, *b*—*Bulimina murchisoniana* d'Orbigny, × 75. *a*, Front view; *b*, Apertural view. (p. 309)

15*a*, *b*—*Bulimina obtusa* d'Orbigny, × 75. *a*, Front view; *b*, Apertural view. (p. 309)

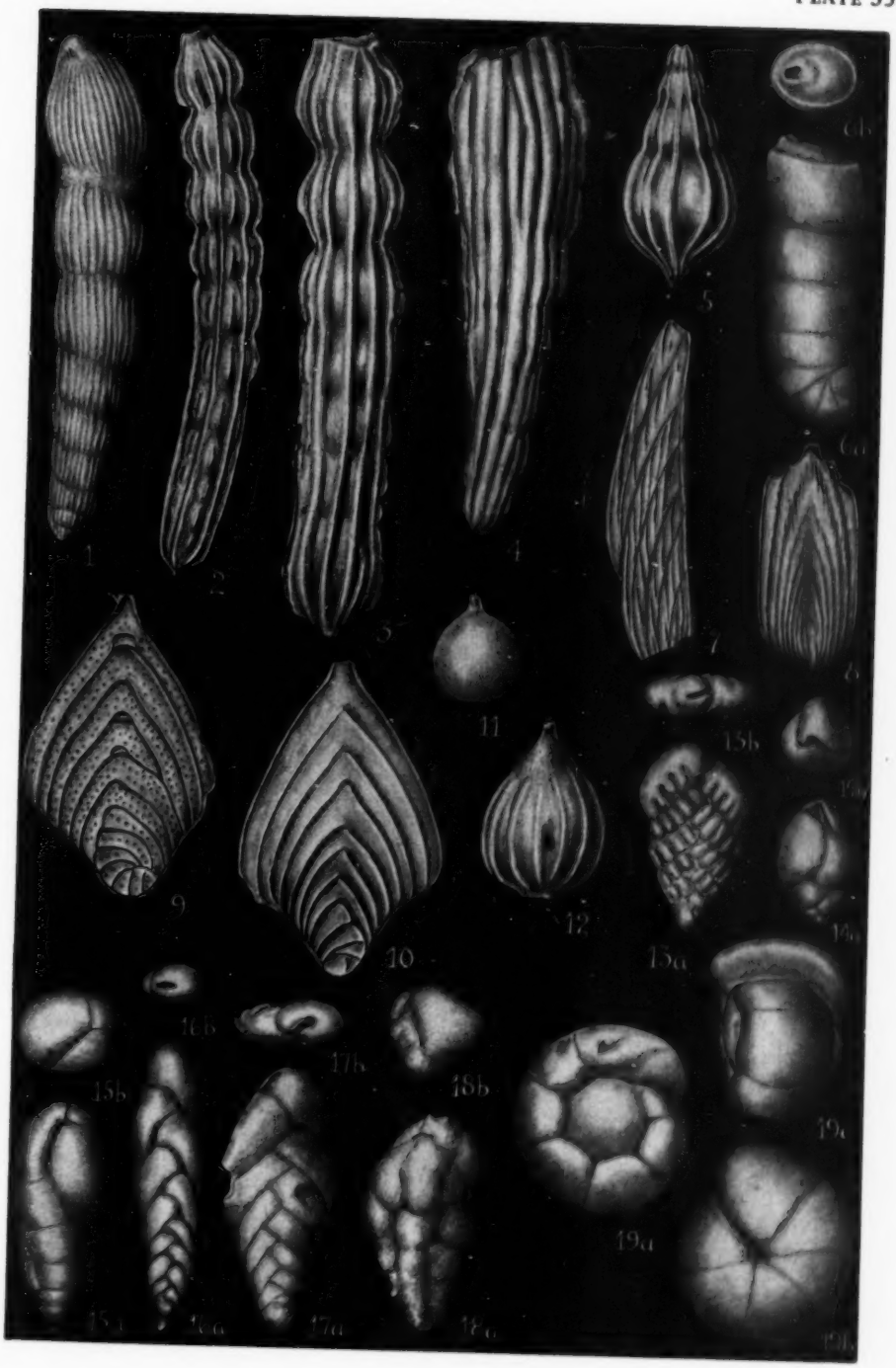
16*a*, *b*—*Loxostomum plaitum* (Carsey), × 75. *a*, Front view; *b*, Apertural view. (p. 310)

17*a*, *b*—*Bolivina incrassata* Reuss, × 40. *a*, Front view; *b*, Apertural view. (p. 310)

18*a*, *b*—*Pseudouvigerina plummerae* Cushman, × 75. *a*, Front view; *b*, Apertural view. (p. 309)

19*a-c*—*Gyroidina globosa* (v. Hagenow), × 75. *a*, Dorsal view; *b*, Ventral view; *c*, Peripheral view. (p. 310)

Figures drawn by Margaret S. Moore



Cushman, Cretaceous Foraminifera

GENUS FRONDICULARIA DEFRANCE, 1824

FRONDICULARIA CORDAI REUSS

Plate 35, figure 8

Frondicularia cordai Reuss, *1845-46,* Verstein. Böhm. Kreide, vol. 1, p. 31, pl. 8, figs. 26-28; pl. 13, fig. 41; vol. 2, p. 108, pl. 24, fig. 38.—Cushman, *1930,* Contr. Cushman Lab. Foram. Res., vol. 6, p. 34, pl. 5, fig. 17.

The figure shows a somewhat broken specimen, but has the characters belonging to this species with very slightly developed longitudinal costae on the chambers. This species occurs in Europe and from the Gulf Coastal Plain of the United States, as well as in the Upper Cretaceous of Trinidad.

GENUS FLABELLINA D'ORBIGNY, 1839

FLABELLINA INTERPUNCTATA VON DER MARCK

Plate 35, figure 9

Flabellina interpunctata von der Marck, *1858,* Verh. nat. Ver. preuss. Rheinl., vol. 15, p. 53, pl. 1, fig. 5.—Reuss, *1860,* Sitz. Akad. Wiss. Wien, vol. 40, p. 216, pl. 9, fig. 1.—Heron-Allen and Earland, *1910,* Jour. Roy. Micr. Soc., p. 422, pl. 8, fig. 5.—Franke, *1912 (1913),* Bronn. Verh. Nat. Hist. Ver., vol. 59, p. 277.—Chapman, *1917,* Bull. Geol. Survey, W. Australia, no. 72, p. 34, pl. 10, fig. 91.—Franke, *1925,* Abhandl. geol. pal. Instit. Univ. Greifswald, vol. 6, p. 64, pl. 5, fig. 13; *1927,* Jahrb. preuss. Geol. Landes., vol. 48, p. 678; *1928,* Abhandl. preuss. Geol. Landes, vol. 111, p. 92, pl. 8, fig. 17.—White, *1928,* Jour. Pal., vol. 2, p. 203.—Cushman, *1930,* Contr. Cushman Lab. Foram. Res., vol. 6, p. 30, pl. 4, figs. 16, 17.

Flabellina rugosa Beissel (not d'Orbigny), *1891,* Abhandl. Kön. Preuss. geol. Landes., vol. 3, p. 47, pl. 9, figs. 20-24.

Frondicularia projecta Carsey, *1926,* Univ. Texas Bull. 2612, p. 41, pl. 6, fig. 5.

Frondicularia baudouiniana Cushman (not d'Orbigny), *1926,* Contr. Cushman Lab. Foram. Res., vol. 2, p. 21, pl. 3, fig. 5; *1927,* Jour. Pal., vol. 1, p. 155, pl. 24, fig. 13.

This is one of the very common and characteristic species of the upper portion of the American and European Cretaceous, widely distributed in the general Gulf Coastal Plain region, Mexico, and Trinidad. The finely papillate character of the chambers and the loop-like extensions from the sutures over the middle of each chamber are characteristic.

FLABELLINA RUGOSA D'ORBIGNY

Plate 35, figure 10

Flabellina rugosa d'Orbigny, *1840,* Mém. Soc. Géol. France, sér. 1, vol. 4, p. 23, pl. 2, figs. 4, 5, 7.—Cushman, *1930,* Contr. Cushman Lab. Foram. Res., vol. 6, p. 32, pl. 4, fig. 15; *1931,* vol. 7, p. 38, pl. 5, fig. 3.

This species originally described by d'Orbigny from the Upper Cretaceous chalks of the Paris Basin occurs in typical form in the

Upper Cretaceous of the general Gulf Coastal Plain region and the West Indies. The early sutures are very highly developed into plate-like costae, and these decrease in height until in the adult the sutures are represented sometimes by depressed lines. This species is particularly abundant in the general Taylor marl section of Texas, and occurs in the upper part of the Ozan formation and Saratoga chalk of Arkansas, and is known from the Upper Cretaceous of wells of Florida and Mexico, as well as from samples slightly below the surface on the island of Antigua.

Genus LAGENA Walker and Jacob, 1798

LAGENA VULGARIS Williamson

Plate 35, figure 11

Lagena vulgaris Williamson, *1858*, Recent Foram. Great Britain, p. 3, pl. 1, figs. 5, 5*a*.

There are a few very smooth forms with an elongate neck which it seems best to refer to this species of Williamson.

LAGENA ACUTICOSTA Reuss

Plate 35, figure 12

Lagena acuticosta Reuss, *1861 (1862)*, Sitz. Akad. Wiss. Wien, vol. 44, pt. 1, p. 305, pl. 1, fig. 4.

Rather typical specimens of this heavily costate form occur in the Saratoga chalk. One of these is figured.

Family HETEROHELICIDAE

Genus BOLIVINOIDES Cushman, 1927

BOLIVINOIDES DECORATA (Jones), var. DELICATULA Cushman

Plate 35, figures 13*a*, *b*

Bolivina decorata Cushman (not Jones), *1926*, Bull. Am. Assn. Petroleum Geol., vol. 10, p. 19, pl. 2, figs. 3*a*, *b*.
Bolivinoides decorata (Jones), var. *delicatula* Cushman, *1928*, Contr. Cushman Lab. Foram. Res., vol. 4, p. 99, pl. 14, fig. 9.

The Saratoga chalk specimens are somewhat variable, but on the whole seem to tend toward the variety rather than the typical form of the species. The lobes of the chambers are very distinct and more like the variety as it is developed in Mexico. It is also known from the Upper Cretaceous of Trinidad.

Genus PSEUDOUVIGERINA Cushman, 1927

PSEUDOUVIGERINA PLUMMERAE Cushman

Plate 35, figures 18*a*, *b*

Pseudouvigerina plummerae Cushman, *1927*, Contr. Cushman Lab. Foram. Res., vol. 3, p. 115, pl. 23, figs. 8*a*, *b*; *1931*, Bull. 41, Tenn. Geol. Survey, p. 46, pl. 7, figs. 15, 16.

This species was originally described from the Pecan Gap chalk of Texas, and has been recorded from the Upper Cretaceous of Tennessee. The specimens from the Saratoga chalk are rare and not usually very well preserved, but seem to belong to this species.

Family BULIMINIDAE

Genus BULIMINA d'Orbigny, 1826

BULIMINA OBTUSA d'Orbigny

Plate 35, figures 15*a*, *b*

Bulimina obtusa d'Orbigny, *1840*, Mém. Soc. Géol. France, sér. 1, vol. 4, p. 39, pl. 4, figs. 5, 6.—Egger, *1899*, Abhandl. kön. bay. Akad. Wiss. München, Cl. II, vol. 21, pt. 1, p. 50, pl. 15, fig. 51.—Cushman and Church, *1929*, Proc. Calif. Acad. Sci., ser. 4, vol. 18, p. 513, pl. 39, figs. 17-19.—Cushman, *1931*, Bull. 41, Tenn. Geol. Survey, p. 47, pl. 7, figs. 17, 18.

Bulimina pupoides Carsey (not d'Orbigny), *1926*, Univ. Texas Bull. 2612, p. 29, pl. 4, fig. 3.

Bulimina quadrata Berry and Kelley (not Plummer), *1929*, Proc. U. S. Nat. Mus., vol. 76, art. 19, p. 5, pl. 2, fig. 7.

This is a very abundant species in the Upper Cretaceous, and is widely distributed in Europe and America. In the Navarro formation of Texas it forms a definite "*Bulimina* zone" which is characterized by great numbers of this species. The microspheric and megalospheric forms are quite different in their shape, the microspheric form being very tapering at the initial end, while the megalospheric form is very broadly rounded.

BULIMINA MURCHISONIANA d'Orbigny

Plate 35, figures 14*a*, *b*

Bulimina murchisoniana d'Orbigny, *1840*, Mém. Soc. Géol. France, sér. 1, vol. 4, p. 41, pl. 4, figs. 15, 16.

This is a very small species composed of comparatively few chambers. Those of the last-formed coil are elongate and strongly overlap the preceding ones. In end view there is a tendency to become triangular with slightly flattened faces and broadly rounded angles.

Genus BOLIVINA d'Orbigny, 1839

BOLIVINA INCRASSATA Reuss

Plate 35, figures 17*a*, *b*

Bolivina incrassata Reuss, *1851,* Haidinger's Nat. Abhandl., vol. 4, p. 29, pl. 4, fig. 13; *1861 (1862),* Sitz. Akad. Wiss. Wien, vol. 44, pt. 1, p. 332.—Egger, *1899,* Abhandl. kön. bay. Akad. Wiss. München, Cl. II, vol. 21, pt. 1, p. 45, pl. 16, figs. 4, 5; *1909,* Sitz. kön. bay. Akad. Wiss. München, p. 23, pl. 1, fig. 18.—Franke, *1925,* Abhandl. geol. pal. Instit. Univ. Greifswald, vol. 6, p. 21, pl. 2, fig. 8.—Cushman, *1926,* Contr. Cushman Lab. Foram. Res., vol. 2, pt. 1, p. 19, pl. 2, figs. 1*a*, *b*; *1927,* vol. 2, pt. 4, p. 86, pl. 12, figs. 1*a*, *b*; *1927* Jour. Pal., vol. 1, p. 161, pl. 28, fig. 11.—Franke, *1928,* Abhandl. Preuss. Geol. Landes., vol. III, p. 153, pl. 14, fig. 6.—White, *1929,* Jour. Pal., vol. 3, p. 43, pl. 4, figs. 19*a*, *b*.—Cushman, *1931,* Bull. 41, Tenn. Geol. Survey, p. 49, pl. 8, figs. 2-4.

This a very distinctive and widely distributed species of the Upper Cretaceous of Europe and America. This species has numerous variations, some of which are undoubtedly of limited vertical range. The walls of the test are thick and smooth although in some forms the sutures become somewhat limbate or even slightly beaded.

Genus LOXOSTOMUM Ehrenberg, 1854

LOXOSTOMUM PLAITUM (Carsey)

Plate 35, figures 16*a*, *b*

Loxostomum plaitum Cushman, *1931,* Bull. 41, Tenn. Geol. Survey, p. 51, pl. 8, fig. 9.
Bolivina plaita Carsey, *1926,* Univ. Texas Bull. 2612, p. 26, pl. 4, fig. 2.
Proroporus plaita Cushman, *1927,* Contr. Cushman Lab. Foram. Res., vol. 2, pt. 4, p. 89, pl. 12, figs. 7*a*, *b*.

This species described by Mrs. Carsey from the Upper Cretaceous of Texas has a wide distribution in the Upper Cretaceous of the Gulf Coastal Plain of the United States. It occurs particularly abundantly in the Navarro formation of Texas and its equivalents elsewhere. It occurs in the Upper Cretaceous of Trinidad. The Saratoga chalk form figured here has slightly limbate chambers tending toward variety *limbosum* Cushman recently described from the Selma chalk of Tennessee.

Family ROTALIIDAE

Genus GYROIDINA d'Orbigny, 1826

GYROIDINA GLOBOSA (v. Hagenow)

Plate 35, figures 19*a-c*

Nonionina globosa v. Hagenow, *1842,* Neues Jahrbuch, p. 574.
Rotalia globosa Reuss, *1861 (1862),* Sitz. Akad. Wiss. Wien, vol. 44, pt. 1, p. 330, pl. 7, figs. 2*a*, *b*.
Gyroidina naranjoensis White, *1928,* Jour. Pal., vol. 2, p. 296, pl. 40, fig. 5.

This species has a particularly rounded periphery, and the ventral side is deep. There are six or seven chambers in the last-formed whorl. It is a form widely distributed in the Upper Cretaceous of Europe and America, occurring in our Gulf Coastal Plain, and in Mexico and Trinidad.

GYROIDINA GIRARDANA (REUSS)
Plate 36, figures 1*a-c*

Rotalina girardana Reuss, *1851,* Zeitschr. deutsch. geol. Ges., vol. 3, p. 73, pl. 5, fig. 34.

Forms similar to that here figured in which the dorsal side is somewhat concave and the margins of the chambers extend out into a definite angle are fairly common in the Saratoga chalk. They are here referred to Reuss's species which has been recorded in this country largely from the Tertiary.

GYROIDINA DEPRESSA (ALTH)
Plate 36, figures 2*a-c*

Rotalina depressa Alth, *1850,* Haidinger's Nat. Abhandl., vol. 3, p. 266, pl. 13, fig. 21.
Gyroidina depressa Cushman and Church, *1929,* Proc. Calif. Acad. Sci., ser. 4, vol. 18, p. 515, pl. 41, figs. 4-6.—Cushman, *1931,* Bull. 41, Tenn. Geol. Survey, p. 54, pl. 9, figs. 7, 8.
Rotalia cretacea Carsey, *1926,* Univ. Texas Bull. 2612, p. 48, pl. 5, figs. *7a, b.*
Rotalia beccarii (Linné), var. *ripleyensis* W. Berry, *1929,* in Berry and Kelley, Proc. U. S. Nat. Mus., vol. 76, art. 19, p. 15, pl. 3, figs. 10-12.

This is one of the commonest species in the Upper Cretaceous of both Europe and America, and has numerous names attached to it. It is of comparatively small size, the spire very much depressed, and is hardly to be confused with any other species.

FAMILY CASSIDULINIDAE

GENUS PULVINULINELLA CUSHMAN, 1926

PULVINULINELLA ALATA (MARSSON)
Plate 36, figures 5*a-c*

Discorbina alata Marsson, *1878,* Mitth. Nat. Ver. Neu-Vorpommern u. Rügen, vol. 10, p. 165, pl. 4, figs. 33*a-d.*
Pulvinulina alata Franke, *1928,* Abhandl. Preuss. Geol. Landes., vol. 111, p. 185, pl. 17, figs. 8*a-c.*
Gyroidina florealis White, *1928,* Jour. Pal., vol. 2, p. 298, pl. 40, figs. 3*a-c.*

Test plano-convex, the ventral side very strongly convex, dorsal side flattened or even slightly concave except in the center which is slightly raised, periphery strongly keeled and developing a flat carina

which is often broken; chambers usually about six or seven in the last-formed whorl, distinct, inflated on the ventral side, but very slightly if at all on the dorsal side; sutures distinct, those of the ventral side sigmoidally curved and very slightly depressed, those of the dorsal side strongly oblique, distinctly limbate; wall smooth, but distinctly perforate; aperture ventral, close to and parallel with the peripheral margin. Diameter 0.90-1.00 mm.; height 0.50 mm.

This species was originally described by Marsson from the Upper Cretaceous of the Island of Rügen. It has also been recorded from the Cretaceous of Germany by Franke. The figured specimens from the Saratoga chalk evidently belong to this species of Marsson as do also specimens from Trinidad from the Upper Cretaceous. This is apparently the same species as that described by White from the Velasco shale of Mexico as *Gyroidina florealis*.

EXPLANATION OF PLATE 36

FIGS. 1*a-c*—*Gyroidina girardana* (Reuss), × 40. *a*, Dorsal view; *b*, Ventral view; *c*, Peripheral view. (p. 311)

2*a-c*—*Gyroidina depressa* (Alth), × 75. *a*, Dorsal view; *b*, Ventral view; *c*, Peripheral view. (p. 311)

3*a*, *b*—*Pullenia quinqueloba* (Reuss), × 75. *a*, Side view; *b*, Peripheral view. (p. 313)

4*a*, *b*—*Pullenia quaternaria* (Reuss), × 75. *a*, Side view; *b*, Peripheral view. (p. 313)

5*a-c*—*Pulvinulinella alata* (Marsson), × 40. *a*, Dorsal view; *b*, Ventral view; *c*, Peripheral view. (p. 311)

6*a-c*—*Planulina taylorensis* (Carsey), × 30. *a*, Dorsal view; *b*, Ventral view; *c*, Peripheral view. (p. 314)

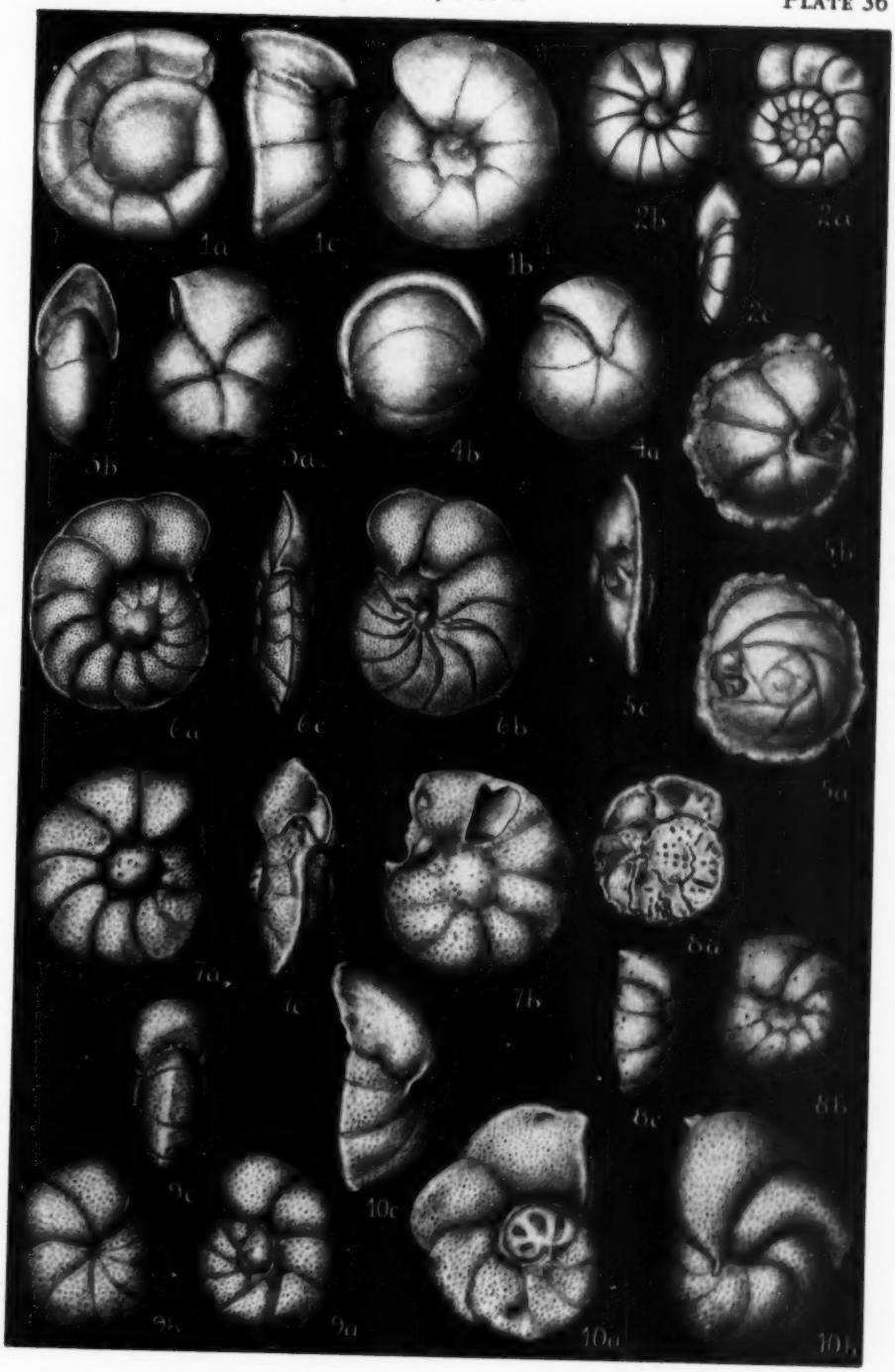
7*a-c*—*Cibicides constricta* (v. Hagenow), × 30. *a*, Dorsal view; *b*, Ventral view; *c*, Peripheral view. (p. 315)

8*a-c*—*Cibicides excolata* (Cushman), × 50. *a*, Dorsal view; *b*, Ventral view; *c*, Peripheral view. (p. 315)

9*a-c*—*Anomalina rubiginosa* Cushman, × 50. *a*, Dorsal view; *b*, Ventral view; *c*, Peripheral view. (p. 314)

10*a-c*—*Cibicides involuta* (Reuss), × 40. *a*, Dorsal view; *b*, Ventral view; *c*, Peripheral view. (p. 315)

Figures drawn by Margaret S. Moore



Cushman, Cretaceous Foraminifera

UNIV. OF MICH.

FAMILY CHILOSTOMELLIDAE

GENUS PULLENIA PARKER AND JONES, 1862

PULLENIA QUINQUELOBA (REUSS)

Plate 36, figures 3*a*, *b*

Nonionina quinqueloba Reuss, *1851*, Zeitschr. deutsch. geol. Ges., vol. 3, p. 71, pl. 5, fig. 31.

Pullenia quinqueloba H. B. Brady, *1884*, Rep. Voy. *Challenger*, Zoology, vol. 9, p. 617, pl. 84, figs. 14, 15.—Cushman and Church, *1929*, Proc. Calif. Acad. Sci., ser. 4, vol. 18, p. 517, pl. 41, figs. 10, 11.—Cushman, *1931*, Bull. 41, Tenn. Geol. Survey, p. 57, pl. 10, figs. 4*a*, *b*.

The Saratoga chalk specimens agree well in their general characters with the figures of Reuss. This common Cretaceous form is widely distributed in Europe and America, and has been recorded through various formations to the present, shown in various localities. It is very evident that all these records do not belong to a single species.

PULLENIA QUATERNARIA (REUSS)

Plate 36, figures 4*a*, *b*

Nonionina quaternaria Reuss, *1851*, Haidinger's Nat. Abhandl., vol. 4, pt. 1, p. 34, pl. 2, fig. 13.

Pullenia quaternaria Olszewski, *1875*, Sprawozd. Kom. Fizyj. Akad. Umiej. Krakowie, vol. 9, p. 118.—Cushman, *1931*, Bull. 41, Tenn. Geol. Survey, p. 57, pl. 10, figs. 5*a*, *b*.

There is a widely distributed spherical species in the Upper Cretaceous of America which seems to be the same as that described by Reuss from the Cretaceous of Central Europe. It was originally described as having four chambers, but most of the American forms have five, the fifth chamber often not showing completely. White has described the species from the Velasco shale of Mexico as *P. coryelli* which according to the figure and description has as many as six or seven chambers in the last-formed whorl. None of our specimens show more than five chambers. However, specimens with six or seven chambers occur in the Upper Cretaceous of Trinidad which is the equivalent of the Velasco shale of Mexico, and it is probable that these two species have a distinctive range.

Family ANOMALINIDAE

Genus ANOMALINA d'Orbigny, 1826

ANOMALINA RUBIGINOSA Cushman

Plate 36, figures 9*a-c*

Anomalina rubiginosa Cushman, *1926,* Bull. Am. Assn. Petroleum Geol., vol. 10, p. 607, pl. 21, figs. 6*a-c*.
Planulina rubiginosa White, *1928,* Jour. Pal., vol. 2, p. 303, pl. 41, figs. 6*a-c*.

This species originally described from the Velasco shale of Mexico occurs typically also in Trinidad. Specimens from the Gulf Coastal Plain region of the United States show much variation, but the general characters are seen in the adult even though they may be lacking in earlier stages.

Genus PLANULINA d'Orbigny, 1826

PLANULINA TAYLORENSIS (Carsey)

Plate 36, figures 6*a-c*

Anomalina taylorensis Carsey, *1926,* Univ. Texas Bull. 2612, p. 47, pl. 6, figs. 1*a, b*.
Planulina taylorensis Cushman, *1931,* Bull. 41, Tenn. Geol. Survey, p. 62, pl. 12, figs. 5*a-c*.

Test large, nearly planispiral, much compressed, later whorls becoming partially evolute, periphery acute and slightly keeled; chambers very distinct, numerous, nine or more in the adult whorls, of nearly uniform shape and very gradually increasing in size as added, centers at each side slightly umbonate; sutures very distinct, curved, slightly depressed in the adult, in the young slightly limbate, and raised on the ventral side; wall mostly smooth, finely but conspicuously perforate; aperture peripheral and extending onto the dorsal side nearly to the center, with a distinct lip. Diameter up to 1.50 mm. or more; thickness 0.10-0.15 mm.

This is a fine large species widely distributed in the Upper Cretaceous of the Gulf Coastal Plain of the United States. It may later be found to be identical with some of the many flattened forms figured by Ehrenberg from various Cretaceous deposits. Very fine, large, well-preserved specimens occur in the Selma chalk of Tennessee.

GENUS CIBICIDES MONTFORT, 1808

CIBICIDES EXCOLATA (CUSHMAN)

Plate 36, figures 8*a-c*

Truncatulina excolata Cushman, *1926,* Contr. Cushman Lab. Foram. Res., vol. 2, pt. 1, p. 22, pl. 3, figs. 2*a, b.*
Gyroidina excolata White, *1928,* Jour. Pal., vol. 2, p. 293, pl. 40, fig. 2.

This species originally described from the Mendez formation of Mexico is generally characteristic of the Taylor marl and related formations of the general Gulf Coastal Plain region of the United States. It is rare in the Saratoga chalk, but nevertheless has its characteristic features well developed.

CIBICIDES CONSTRICTA (V. HAGENOW)

Plate 36, figures 7*a-c*

Rotalia constricta v. Hagenow, *1842,* Neues Jahrbuch, p. 571.—Reuss, *1861 (1862),* Sitz. Akad. Wiss. Wien, vol. 44, pt. 1, p. 329, pl. 6, fig. 7.

Such forms as that figured here from the Saratoga chalk seem to be identical with v. Hagenow's species as figured by Reuss. Both sides are strongly umbonate, and the umbo itself is pitted. The walls are also coarsely perforate, and the periphery is slightly keeled.

CIBICIDES INVOLUTA (REUSS)

Plate 36, figures 10*a-c*

Rotalia involuta Reuss, var., *1861 (1862),* Sitz. Akad. Wiss. Wien, vol. 44, pt. 1, p. 313, pl. 2, figs. 4*a, b.*

The figured specimen from the Saratoga chalk is very similar to the specimens figured in the above reference by Reuss. It is like most of these attached forms more or less variable in its characters.

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NOTES ON THE SARATOGA CHALK[1]

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ABSTRACT

The Saratoga chalk lies upon Marlbrook marl and beneath Nacatoch sands. It outcrops in southern Arkansas but is covered by younger formations south of the outcrop in Arkansas, and in northwestern Louisiana, and the extreme northeastern part of Texas. Literature has formed the basis for compiling data on the mega-fauna, but collections from the field on the microfauna. The great number of Taylor (Marlbrook) species in the Saratoga suggests a Taylor relationship.

INTRODUCTION

Saratoga, Arkansas, is the type locality for the chalk bearing that name and outcropping north, east, and west of the town. R. T. Hill, in 1888, included this white chalk in the "Marlbrook, Columbus or *Gryphaea vesicularis* chalk marls."[2] Ten years later, J. C. Branner raised its status to that of a formation and named it Saratoga. J. A. Taff, in 1902, described the formation and its type locality in detail. A view essentially like that of Dr. Hill was taken by A. C. Veatch in 1906 when he considered the Saratoga to be a chalky phase of upper Marlbrook. L. W. Stephenson, in 1927, assigned the Saratoga to basal Navarro, leaving the Marlbrook marl in the upper Taylor.[3] Most of the succeeding papers have followed this correlation, although there are still a considerable number of workers who adhere to Dr. Hill's view.

The Saratoga may be defined as the chalk which rests normally upon the Marlbrook and beneath the Nacatoch. It is the chalk phase of the section immediately underlying the Nacatoch formation.

[1] Published by permission of the chief geologist of The Pure Oil Company.

[2] C. H. Dane, "Upper Cretaceous Formations of Southwestern Arkansas," Ark. Geol. Surv., Bull. 1, p. 98, 1929.

[3] L. W. Stephenson, "Notes on the Stratigraphy of the Upper Cretaceous Formations of Texas and Arkansas," Bull. Am. Assn. Petroleum Geol., Vol. 2, pp. 1-17, 1927.

Doubtless many marls, shales and sands elsewhere are equivalent to this chalk but are not included in the tongue or formation carrying the name. It is difficult to identify shale and sand equivalents of the Saratoga. As chalks grade laterally into other sediments the faunal facies change, and, unless there is a fairly continuous series of outcrops to reveal the change of lithology, it may be difficult to make accurate correlation. One may be able to say that there is Marlbrook below and Nacatoch above and that sediments between with indeterminate fauna are approximately Saratoga in age. The Exogyras have been used very widely along the Gulf coast in making correlations, and probably the presence of *Exogyra cancellata* Stephenson in the lower *Exogyra costata* Say zone indicates a Saratoga equivalent in spite of any variation in lithology. Glauconite outcropping at the base suggests an unconformity or faunal break, while nonfossiliferous sands and glauconite occurring above also represent a faunal break.

DISTRIBUTION

The Saratoga chalk comes to the surface in a scattered line of outcrops in southern Arkansas, from Saratoga to Blevins and eastward from Okolona to Arkadelphia. There seem to be no records of outcrops in other states. Many wells drilled in Arkansas, Louisiana, and Texas have encountered a chalk with the same characteristics and fauna as those of the chalk outcropping at Saratoga. The subsurface distribution lies east of the East Texas geosyncline, on the Sabine uplift, and eastward, in the counties of Rusk, Harrison, and Shelby and in the parishes of Sabine and Natchitoches, and farther northeastward into Arkansas beyond El Dorado. Below is a list of a few of the wells which have cored Saratoga chalk:

TABLE I

WELLS FROM WHICH CORE SAMPLES OF SARATOGA CHALK HAVE BEEN OBTAINED

State	County-Parish	Farm and Well	Company	Depth of core
Arkansas	El Dorado	Gaddy No. 1	Pure Oil Co.	2310
Louisiana	Natchitoches	Collins No. 1	William Coates	2253
Louisiana	Sabine	Peavy Wilson No. 1	Loring Oil Co.	3033
Louisiana	Sabine	Bowman-Hicks No. 1	Standard Oil	2368
Texas	Shelby	Carraway No. 1	Gulf Prod. Co.	1455
Texas	Sabine	Mills No. 1	Benedum & Trees	2900
Texas	Harrison	Davenport No. 1	Sinclair O. & G.	2420

In many wells, marls and sandy shales and sands hold the approximate position of the chalk, and in some of the shales there is sufficient faunal evidence for correlation with the Saratoga. In most cases definite evidence has not been obtained, although it appears that sediments of Saratoga age are much more widespread than the actual distribution of the chalk.

MEGA-FOSSILS

The following information has been compiled from the literature, using several publications, chiefly Dane's excellent bulletin, "Upper Cretaceous Formations of Southwestern Arkansas."

Below is a list of fossils which are reported to occur in the Saratoga:

Mega-fossils from the Saratoga chalk

Cliona sp.
Unidentified sponges.
Serpula sp.
Hemiaster sp.
Micraster sp.
Bryozoa.
Cucullaea aff. antrosa Morton.
Inoceramus sp.
Glycymeris sp.
Gryphaea vesicularis (Lamarck).
Exogyra costata Say.
Exogyra cancellata Stephenson.
Pachycardium spillmani Conrad.
Trigonia sp.
Pecten sp.
Pecten sp.
Paranomia scabra (Morton).
Anatimya antiradiata Conrad.
Cuspidaria sp.
Liopistha protexta Conrad.
Veniella conradi (Morton).
Veniella (Etea) sp.
Trapezium sp.
Crassatellites sp.
Epitonium sp.
Cardium sp. (large).
Isocardia sp.
Cyprimeria densata Conrad.
Panope sp.
Sauvagesia ?
Capulus ?
Gyrodes cf. altispira (Gabb).
Turritella trilira Conrad.
Anchura sp.
Ornopsis ?
Sargana sp.
Volutoderma sp.
Scaphites sp.
Baculites sp.
Eutrephoceras sp.
Nostoceras helicinum (Shum.)?
Pachydiscus sp.
Belemnitella americana (Morton).
Scalpellum sp.
Fish teeth.

We have taken the faunal lists of Cretaceous formations in the area under consideration and have charted them in order to obtain a

graphic representation of the published range of the Saratoga fossils. Instead of presenting the graph, we are noting some of the peculiarities which it shows.

Of the Saratoga fossils we have noted the following:

Fossils Not Listed as Occurring Above the Saratoga	*Fossils Not Listed as Occurring Below the Saratoga*
Cliona sp.	Bryozoa sp.
Cardium sp.	*Cardium sillmani.
*Exogyra cancellata	*Exogyra costata.
Pecten sp.	Epitonium sp.
Veniella (Etea) sp.	Glycymeris sp.
Gyrodes ?	*Liopistha protexta.
Volutoderma sp.	Capulus ?
Eutrophoceras sp.	*Gyrodes cf. altispira.
	*Turritella trilira.
	*Belemnitella americana.
8 fossils	10 fossils
*1 with specific identification	* 6 with specific identification

This suggests that the Saratoga is more closely related to some formation above than it is to any formation below. Since the Nacatoch immediately overlies the chalk it is natural to suppose that the Saratoga may be more closely related to it than to any other formation.

Below are listed the Nacatoch fossils:

Fossils Occurring in the Saratoga But Not Listed in the Arkadelphia	*Fossils Occurring in the Arkadelphia but not Listed in the Saratoga*
Hemiaster sp.	Coral.
Serpula sp.	Gryphaea sp. (small)
Bryozoa.	*Pecten simplicius.
*Cardium sillmani.	Cucullaea sp.
*Gryphaea vesicularis.	Nucula sp.
Epitonium sp.	Turritella sp.
Glycymeris sp.	Dentalium sp.
*Liopistha protexta.	
*Paramonia scabra.	
Trigonia sp.	
Capulus ?	
*Gyrodes cf. altispira.	

*Turritella trilira.
Pachydiscus sp.
*Belemnitella americana.

15 fossils
* 7 with specific determination

7 fossils
*1 with specific determination

This suggests that the Nacatoch is more closely related to the Saratoga than to the Arkadelphia. If we consider this to be the case we can group the Nacatoch and Saratoga fossils together, and using this new list see whether it appears to be more like those of lower or upper formations.

Saratoga-Nacatoch Fossils Listed only in Formations Below

Cliona.
Hemiaster sp.
*Hamulus onyx.
Serpula.
Cardium.
*Gryphaea vesicularis.
Inoceramus sp.
*Inoceramus aff. barabini.
*Ostrea plumosa.
*Ostrea mesentrica.
*Ostrea falcata.
*Ostrea tecticosta.
Pecten.
*Anomia argentaria.
Aphrodrina ?
Corbula sp.
Legumen sp.
Lima sp.
*Liopistha bella.
*Paramonia scabra.
Spondylus sp.
Trigonia sp.
Veniella (Etea) sp.
Anchura sp.
Anisomyon ?

Saratoga-Nacatoch Fossils Listed only in Formations Above

*Exogyra costata
Gryphaea sp. (small)
*Pecten simplicius.

Volutomorpha sp.
Volutoderma sp.
Eutrephoceras sp.
Pachydiscus sp.
Nostoceras sp.

30 fossils
*10 with specific identification
5 fossils in both Nacatoch and Saratoga and below.
* 2 with specific identification
18 fossils in Nacatoch (but not in Saratoga) and below.
* 8 with specific identification.
7 fossils in Saratoga (but not in Nacatoch) and below.

3 fossils
*2 with specific identification
1 fossil in Saratoga and Nacatoch and above.
* 1 with specific identification
2 fossils in Nacatoch (but not in Saratoga) and above.
* 1 with specific identification.

This suggests that the Saratoga-Nacatoch fossils were more abundant in pre-Saratoga time than in post-Nacatoch time.

Taking the same Saratoga-Nacatoch list the following distribution of species may be noted:

Fossils Occurring in the Marlbrook but not in the Arkadelphia	*Fossils Occurring in the Arkadelphia but not in the Marlbrook***
*Gryphaea vesicularis	Coral
*Ostrea plumosa	*Exogyra costata
*Ostrea falcata	Gryphaea sp. (small)
*Ostrea tecticosta	*Pecten simplicius
*Anomia argentaria	Cucullaea
*Paranomia scabra	Nucula sp.
	*Veniella conradi.
	Dentalium sp.
	Turritella sp.
	Scaphites sp.
	Baculites sp.
	Crassatellites sp.
6 fossils	12 fossils
	* 3 with specific identification
*6 with specific identification	**All but three of these are listed in formations below the Marlbrook.

In this case the apparent relationship is not as one-sided as in the others. It does suggest that the Saratoga and Nacatoch are somewhat related to the Marlbrook, possibly more so than has been commonly supposed. We admit that the lists are not complete, although they are much more complete and accurate than any lists which we could make from personal field experience. The lists came from several sources. Genera have been given where species were not determined and species are given even when they had to be questioned. In fact the lists were taken as we found them and the work of charting and separating was purely mechanical, without prejudice. In this lies whatever merit there is to the method. We obtained results surprising to ourselves and we merely record them for their apparent value.

Exogyras are extensively used for Upper Cretaceous correlation along the Gulf Coast, since they are among the most widespread, reliable, and abundant index fossils. It is true that particular species may change their positions in the geologic column when great horizontal distances are considered, but the Exogyras seem to remain remarkably constant when one considers the many different types of material in which they are found. Concerning them Dane says:[4]

> The type of *Exogyra cancellata* Stephenson characterized by strongly developed but cancellated costae occurs typically and in greatest abundance in the Saratoga chalk, but a few specimens approaching the typical form occur also in the upper part of the underlying Marlbrook marl.—p. 107.
>
> The lower limit of strongly costate types of *Exogyra cancellata* is the base of the Saratoga, although specimens properly referable to that genus [meaning species ?] are found in the upper part of the Marlbrook, but probably not below its uppermost 50 feet.—p. 107.
>
> The base of the Saratoga chalk clearly marks the base of the beds of Navarro age in Arkansas and the base of the *Exogyra costata* zone, the importance of which in correlation has been pointed out by Stephenson. The thinner *Exogyra cancellata* subzone includes the lower part of the Saratoga and extends downward stratigraphically a short distance into the uppermost Marlbrook. *Exogyra cancellata* of the type found in the Saratoga has been found at several places in the lower part of the Navarro in northeastern Texas, showing that the Saratoga is of lower Navarro age.—p. 111.
>
> If the evolutionary change in the genus *Exogyra* could be taken as even a rude measure of the time that elapsed, the break between the Marlbrook and the Saratoga might represent as much time as was required for the deposition of the Brownstown, Ozan, Annona, and Marlbrook. The establishment of the costate tendency shown in the uppermost Marlbrook probably required more

[4] C. H. Dane, "Upper Cretaceous Formations of Southwestern Arkansas," Ark. Geol. Surv., Bull. 1 (1929).

time than that required for its progression to completion, and presumably also the evolution was accelerated in the lost interval by changing conditions, so the lost interval probably represents less time than would at first be thought. However, it appears that from Hunt to Falls County, in east-central Texas, there is about 200 feet of the *Exogyra cancellata* zone, most of which is certainly later than the top of the Marlbrook; yet above this zone in Texas there is probably an unconformity at the base of the *Exogyra costata* zone. The time importance of the Saratoga-Marlbrook unconformity is therefore greater than the 200 feet of the *Exogyra cancellata* zone in east-central Texas.—pp. 111-112.

This list [of Arkadelphia fossils—not included here], though incomplete, is sufficient to establish close faunal relationship of the Arkadelphia with the Saratoga and the Nacatoch. The striking feature of the fauna is the apparent abrupt change in the species *Exogyra costata Say,* which assumes [in the Arkadelphia] a distinct and easily recognizable varietal form. The costae, although strong and uninterrupted, become narrow and have broader grooves between them, presenting a sharp contrast with the broad costae and narrow grooves of the typical *Exogyra costata.* The lines of growth intersecting the costae occasionally produce a slightly nodose effect, but the cancellated form is not found. Specimens of this variety have been found at the very base of the Arkadelphia, and although most of the upper part of the Nacatoch is not fossiliferous there is nothing to indicate that the more strongly costate Nacatoch form does not continue to the top of that formation unchanged.—p. 149.

It seems to the writers that the cancellate forms of *Exogyra* in the Marlbrook suggest a close relationship to the Saratoga. While it is clear that the complete record of development has been broken there remains much to suggest a very close relationship between Marlbrook (upper Taylor) and Saratoga. Some evolutionary changes take place slowly while others take place suddenly; still others begin slowly and, gathering momentum, complete the transformation very rapidly. We have heard of cancellate or costate Exogyras far down in the *Exogyra ponderosa* zone. They are not persistent nor widespread but they do suggest that certain conditions are favorable for that kind of development and that such development is fairly easy and rapid when the proper conditions do exist. If the presence of *Exogyra cancellata* is the determining factor, then the Marlbrook, which in places contains this species, must be separated from the Saratoga mainly on abundance and development of specimens. Also if the presence of a few shells of *Exogyra cancellata* in the Navarro causes the Saratoga to be linked with the Navarro, then the presence of *Exogyra cancellata* in the upper part of the Marlbrook should also link it with the Marlbrook. Perhaps we have made mistakes in our presentation of the facts. These suggestions have been based on the

literature and not on field work but the striking similarity to the general changes of the micro-faunas seems worthy of note. Our only purpose in mentioning the larger fossils is to show that we have found some parallelism between the developments of mega- and micro-faunas.

MICRO-FOSSILS

The following foraminifera are common in the Saratoga at the type locality:

Foraminifera of the Saratoga chalk at the type locality

Flabellammina saratogaensis n.sp.
Spiroplectammina anceps (Reuss)
Gaudryina minima Egger
Gaudryina pupoides d'Orbigny
Gaudryina chapmani Franke
Gaudryina oxycona Reuss
Heterostomella foveolata (Marsson)
Clavulina amorpha Cushman
Clavulina trilatera Cushman
Clavulina trilatera Cushman, var.
Arenobulimina presli (Reuss)
Robulus navarroensis (Plummer)
Marginulina elongata d'Orbigny
Dentalina megapolitana Reuss
Dentalina confluens Reuss
Nodosaria affinis Reuss
Saracenaria italica Defrance
Vaginulina cf. simondsi Carsey
Frondicularia cordai Reuss
Flabellina interpunctata v. Marck
Flabellina rugosa d'Orbigny
Lagena vulgaris Williamson
Lagena acuticosta Reuss
Polymorphinidae
Bolivinoides decorata (J. Wright)
Pseudouvigerina plummerae Cushman
Bulimina obtusa d'Orbigny
Bulimina murchisoniana d'Orbigny
Bolivina incrassata Reuss
Loxostomum plaitum (Carsey)
Gyroidina globosa (v. Hagenow)
Gyroidina girardana (Reuss)
Gyroidina compressa (Alth)
Pulvinulinella alata (Marsson)
Pullenia quinqueloba Reuss
Pullenia coryelli White
Anomalina rubiginosa Cushman
Planulina taylorensis (Carsey)
Cibicides excolata (Cushman)
Cibicides constricta (v. Hagenow)

Dr. Cushman has kindly made the above identifications from our material and is presenting the specific descriptions and illustrations in another article. He is in no way responsible for the ideas expressed in our paper but it is through his kindness and coöperation that we have been able to obtain a correct list of the foraminifera. We greatly

appreciate his helpfulness and his willingness to identify the faunas from the type localities of the other chalks.

Gyroidina michelini d'Orbigny occurs rarely in the lower Saratoga. It is not included because of its rarity but will be listed when the Pecan Gap is considered. This species has been widely used as one of the index micro-fossils of the Taylor. It began as a dwarf form in upper Austin time and appears to have become extinct in the lower Saratoga.

Heterostomella faveolata (Marsson) is closely related to upper Taylor forms and is possibly identical to them. It is different from middle Taylor varieties and from anything we have seen in the Navarro.

Bolivinoides decorata (J. Wright) has been considered by some an index fossil of the upper Taylor marls and chalks. It is abundant in the Annona, and in the upper Pecan Gap chalk, and above in the upper Taylor. It continues to be abundant in the Saratoga.

Cibicides excolata (Cushman) is abundant in the Annona, in the upper Pecan Gap chalk and the marls above, and also in the Saratoga. It becomes extinct in the Saratoga or in the lower Nacatoch.

Cibicides constricta (v. Hagenow) is characteristically abundant in parts of the Saratoga.

Planulina taylorensis (Carsey) has been widely used as an index fossil of the Taylor. Its large size, abundance and characteristic appearance make it easy to identify. Many regard the last of *P. taylorensis* as marking the top of Taylor. Expressed in another way, the first specimens encountered in drilling are considered to indicate the top of the Taylor formation. This is probably not correct but it is an easy way of locating an arbitrary correlation horizon which may be useful locally. Lithology has much to do with the presence or absence of this fossil. It is found best developed in marls and very rarely in sands, and it ranges from lower Taylor into the Saratoga chalk. At the type locality of the Saratoga it is abundant only in the lower chalk above the basal glauconite.

Robulus navarroensis (Plummer) is included in the list. The specimens in the Saratoga are not typical of the species in the Navarro and we believe that they are distinguishable from them and therefore will not cause confusion. It is possible that this is the chalk variety, and that where the Saratoga equivalent is a shale it contains typical *R. navarroensis*. However, we have no evidence for this.

It is no wonder that students of micro-faunas are inclined to link the Saratoga with the Marlbrook and upper Taylor. Practically all of the characteristic micro-fossils of the upper Taylor are common in the Saratoga at its type locality. *Gyroidina michelini* d'Orbigny is the one notable exception, for it is very rare. Practically none of the characteristic Navarro (restricted) fossils are found in the Saratoga. There is at least one exception to this. The curved variety of *Clavulina trilatera* Cushman is one of the very few Saratoga fossils which is typical of the Navarro. *Anomalina rubiginosa* Cushman is abundant in the Nacatoch and Taylor. For the most part the other fossils have not been found to be particularly characteristic of any of the formations. The simple gaudryine, clavuline, bulimine, and gyroidine representatives throw little light on the question. After all, the specialized, bizarre species are the ones which are short-lived and are therefore the ones best suited for correlation. They are the ones which disappear when conditions change and it was the specialized Taylor group of fossils which became extinct during and at the end of Saratoga time.

Like the larger fossils, the micro-fossils of the Saratoga made their great advance before the time of the chalk we are discussing, and they acquired most of their characters and underwent most of their evolution between the middle Pecan Gap and the top of the Marlbrook. Then there was a slight break, a few new species developed or drifted in, but the bizarre types continued over the break and dominated the foraminiferal life of the Saratoga. The Nacatoch above the Saratoga has a very meager micro-fauna. Later when marl conditions returned in the Arkadelphia (Navarro) the fauna was very different and even when Navarro chalks were deposited the micro-fauna did not show any recurrence of Saratoga or earlier forms.

SUMMARY

One might expect the Nacatoch to be the basal sand of the Navarro, and the Saratoga to be the top of the Taylor. However, the large number of Nacatoch mega-fossils in the Saratoga does not support this. On the other hand the glauconite at the base of the Saratoga might separate the Taylor from the Navarro. The ranges of the micro-fossils are opposed to this and the mega-fossils do not give much support. Nevertheless the Taylor and Navarro faunas are distinct. There may have been continued deposition, except for short intervals, from the Taylor through the Saratoga and throughout the

Nacatoch. The lower fossiliferous sandy shale of the Nacatoch might be considered as a continuation of Saratoga, but under less favorable conditions, and the nonfossiliferous sands of the upper Nacatoch might represent the faunal break between fossiliferous formations. This arrangement does not satisfy us and we shall leave it for others to settle.

The Saratoga is the chalk developed between the Marlbrook and the Nacatoch over a relatively limited area. It has a distinctive fauna and can be identified both from mega- and micro-fossils on the outcrop and from micro-fossils in wells. Other chalks of the Cretaceous are equally distinctive and we hope to discuss some of them and their faunas in the near future.[5]

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LATE CRETACEOUS FORAMINIFERA FROM TABASCO, MEXICO

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ABSTRACT

Fifty-six species of small foraminifera are described, of which eleven are new.

The foraminifera described and figured in this paper came from near Puenta Piedra, on the Rio Puscatan, 19 kilometers south of Macuspana, Tabasco, Mexico (Loc. 5-61-3). The material was collected in 1923 by Mr. Bond Coleman, at that time with the International Petroleum Company.

The material came from the surface, and consists of yellow, argillaceous shale, only slightly indurated, which contains abundant foraminifera but no other fossils. The rocks of this region are highly folded and faulted, being overthrust from the south, bringing upper Cretaceous shales over lower and middle Tertiary shales. The age of any particular exposure can be determined only by the foraminiferal fossils.

The fossils are well preserved, filled with calcite and in part silicified. Many specimens are distorted, due to the movement of the enclosing shale. All the species came from the same sample of shale.

The fauna is a generalized, cosmopolitan one, consisting mostly of long-ranging forms, with relatively few specialized species, which can be definitely ascribed to any particular horizon. On superficial study the fauna seems to have no definite age or locality characteristics, being similar to numerous faunas occurring in Cretaceous, Tertiary, and Recent deposits in many parts of the world, but agreeing on the whole with none. Such typically Cretaceous forms as *Pseudotextularia, Globotruncana, Karreria, Gümbelina, Eouvigerina, and Globigerina cretacea* are missing. On the other hand, such typically Tertiary forms as the Orbitoididae, nummulites, *Amphistegina, Uvigerina,*

Polymorphina, Cyclammina, and *Hantkenina* are likewise absent. These is also a notable absence of the porcellaneous forms, and also of the Astrorhizidae.

Nevertheless, by careful identification and analysis of the fauna, and by application of the three best methods of correlation, viz., percentage of species common to this and to known horizons, index fossils, and guide fossils, the age of the fauna can be determined as late Cretaceous. The age is probably the same as that of the Velasco shale of the Panuco region of eastern Mexico.

A useful check on the age of the fauna exists in the occurrence of a more typical Cretaceous fauna eight kilometers south of Puenta Piedra, which has many species in common with the present fauna, and also has several typical Upper Cretaceous foraminifera, such as *Globigerina cretacea, Eouvigerina cretacea* and *Gümbelina globulosa.*

The fauna was probably deposited in deeper water than the average fauna found in geologic deposits, which explains the absence of the more specialized forms, which live for the most part in very shallow water.

There are included in this paper the descriptions and figures of fifty-six species, belonging to thirty-five genera. There are eleven new species.

Of the forty-five old species, thirty-two are too simple in structure or long-ranging to be of much value in correlation. The remaining thirteen more specialized forms, with the horizons from which they were originally named, are the following: *Cibicides dekayi, Gyroidina florealis, Discorbis inflata, Spiroplectammina rosula,* and *Turrilina trochoides,* from the Upper Cretaceous; *Gyroidina soldanii octocamerata* and *Planulina scrobiculata,* from the Eocene; *Bulimina declivis* and *Virgulina mustoni,* from the Oligocene; *Cibicides pachyderma* and *Ellipsopolymorphina schlichti,* from the Miocene; *Bulimina laevigata,* from the Pliocene; and *Textularia mexicana,* from the Recent. It will be thus seen that a plurality of the more complex forms, although embracing only five species out of a total of fifty-six in the whole fauna, are index fossils of the Upper Cretaceous.

It is on account of the unusually simple character of this fauna, the difficulty in identifying the species and the age, and to demonstrate the reliability of even such simple foraminifera in correlation, that this study is published. These are the first small foraminifera which have been described from Tabasco.

SYSTEMATIC DESCRIPTIONS

FAMILY AMMODISCIDAE RHUMBLER, 1895

GENUS GLOMOSPIRA RZEHAK, 1888

GLOMOSPIRA CHAROIDES (JONES AND PARKER)

Plate 37, figures 1, 2

Trochammina squamata charoides Jones and Parker, *1860,* Quart. Jour. Geol. Soc., vol. 16, p. 304. (Recent).
Trochammina charoides Carpenter, *1862,* Intro. Foram., p. 141, pl. 11, fig. 3. (Recent).
Ammodiscus charoides Brady, *1884,* Rep. Voy. *Challenger,* Zool., vol. 9, p. 334, pl. 38, figs. 10-16. (Recent).
Glomospira charoides Cushman, *1925,* Smiths. Misc. Coll., vol. 77, no. 4, p. 25, pl. 2, fig. 12. (Recent).

Test tubular, of even diameter, regularly coiled in a low spire making a spheroidal or discoidal form; sutures distinct, slightly depressed; wall silicified and hyaline, and does not appear to have been arenaceous; surface smooth and finely punctate; aperture the open end of the tubular chamber. Diameter, 0.2–0.35 mm. Abundant.

Our specimens have been distorted in the folding of the enclosing shale. It is doubtful if the wall of *Glomospira* is arenaceous as has been assumed by various authors.

FAMILY SPIRILLINIDAE RHUMBLER, 1895

GENUS SPIRILLINA EHRENBERG, 1843

SPIRILLINA VIVIPARA (EHRENBERG)

Plate 37, figure 3

Spirillina vivipara Ehrenberg, *1841,* Abhandl. k. Ak. Wiss. Berlin, p. 422, pl. 7, fig. 41. (Recent).

Our specimens are typical, except that many of them are distorted, assuming an oval shape, probably due to the movement of the enclosing shale, but they are not broken. The walls are hyaline and entirely siliceous. We interpret the wall to have been originally calcareous and hyaline, inasmuch as specimens of other associated genera which were originally calcareous, are now silicified. There are numerous growth lines and the surface is minutely pitted, but mural pores are not definitely discernible. Diameter, 0.3–0.8 mm. Common.

FAMILY TROCHAMMINIDAE SCHWAGER, 1877

GENUS TROCHAMMINA PARKER AND JONES, 1859

TROCHAMMINA DIAGONIS (CARSEY)

Plate 37, figure 4

Haplophragmoides diagonis Carsey, *1926*, Univ. Texas, Bull. 2612, p. 22, pl. 3, fig. 1. (Cretaceous).

Trochammina diagonis Cushman, *1927*, Contrib. Cushman Lab. Foram. Res., vol. 2, pt. 4, p. 84, pl. 10, fig. 7. (Upper Cretaceous).

Test trochoid, very much compressed; peripheral margin sharply rounded; periphery lobulate; chambers five to six in the last whorl; sutures distinct, depressed, slightly curved on the dorsal side; radial on the ventral side; wall finely arenaceous; surface smooth; aperture an elongate slit on the inner margin of the last-formed chamber, extending from the umbilicus nearly to the periphery. Diameter, 0.26–0.4 mm. Common.

As is common with this species, the Tabasco specimens have been compressed dorso-ventrally and otherwise distorted by the movement of the enclosing shale.

EXPLANATION OF PLATE 37

FIGS. 1, 2—*Glomospira charoides* (Jones and Parker), 1, × 35; 2, × 140. (p. 331)

3—*Spirillina vivipara* (Ehrenberg), × 40. (p. 331)

4*a*, *b*—*Trochammina diagonis* (Carsey), × 80. *a*, Side view; *b*, Edge view. (p. 332)

5*a*, *b*—*Haplophragmoides deformis* (Andreae), × 70. *a*, Apertural view; *b*, Side view. (p. 333)

6*a*, *b*—*Haplophragmoides eggeri* Cushman, × 80. *a*, Edge view; *b*, Side view. (p. 333)

7*a*, *b*—*Cyclammina pusilla* Brady, × 50. *a*, Side view; *b*, Edge view. (p. 333)

8*a*, *b*—*Gaudryina indentata* Cushman and Jarvis, × 40. *a*, Side view; *b*, Apertural view. (p. 334)

9*a*, *b*—*Clavulina amorpha* Cushman, × 35. *a*, Side view; *b*, Apertural view. (p. 334)

10—*Spiroplectammina rosula* (Ehrenberg), × 70. (p. 335)

11*a*, *b*—*Spiroplectammina bentonensis* Carman, × 60. *a*, Side view; *b*, Cross-section. (p. 334)

12*a*, *b*—*Textularia mexicana* Cushman, × 40. *a*, Side view; *b*, Apertural view. (p. 335)

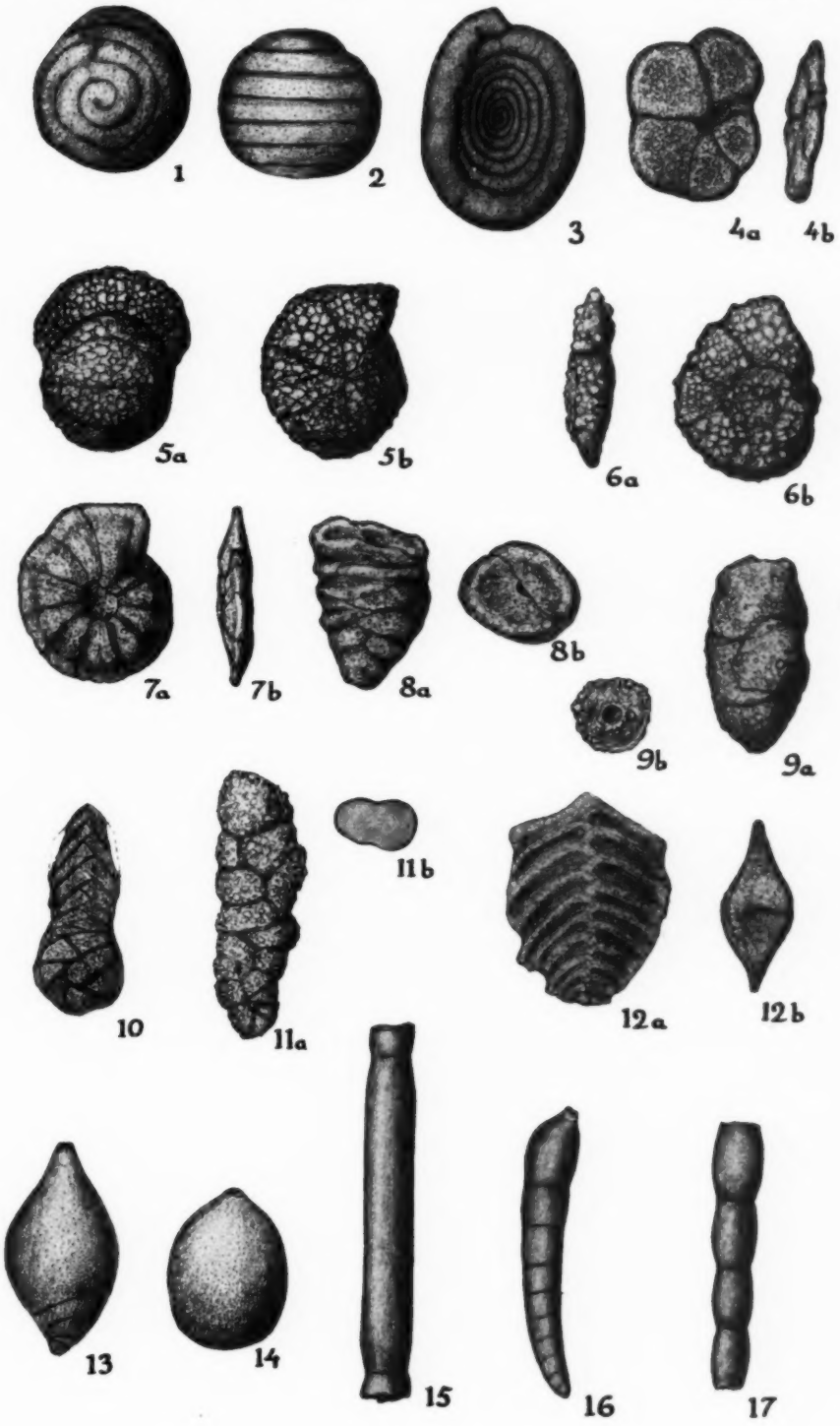
13—*Psecadium aduncum* (Costa), × 90. (p. 336)

14—*Oolina inornata* d'Orbigny, × 105. (p. 336)

15—*Nodosaria arundinea* Schwager, × 35. (p. 337)

16—*Dentalina böttcheri* Reuss, × 30. (p. 336)

17—*Nodosaria consobrina* (d'Orbigny), × 40. (p. 337)



Galloway and Morrey, Cretaceous Foraminifera

GENUS HAPLOPHRAGMOIDES CUSHMAN, 1910

HAPLOPHRAGMOIDES DEFORMIS (ANDREAE)

Plate 37, figure 5

Haplophragmium deforme Andreae, *1884,* Abh. geol. Specialkarte, Elsass-Loth., vol. 2, pt. 3, p. 197, pl. 8, fig. 1. (Middle Oligocene).

Test spheroidal, bilaterally symmetrical; chambers five or six in the last whorl; sutures narrow, indistinct, slightly curved; wall coarsely arenaceous; surface rough; aperture a curved slit at the base of the septum. Diameter, 0.35 mm. Rare.

HAPLOPHRAGMOIDES EGGERI CUSHMAN

Plate 37, figure 6

Haplophragmium fontinense Egger (not Terquem), *1907-1909 (1910),* Berichte, Naturw. Ver. Regensburg, vol. 12, p. 95, pl. 3, figs. 16-18. (Upper Cretaceous).

Haplophragmoides eggeri Cushman, *1926,* Bull. Am. Assn. Petroleum Geol., vol. 10, no. 6, p. 583, pl. 15, fig. 1. (Upper Cretaceous).

Test compressed, oval in outline; chambers six or seven in the last coil, slightly inflated; sutures slightly depressed, discernible only in the last part of the last whorl; wall coarsely arenaceous; surface rough; aperture an obscure slit at the base of the septal face. Diameter, 0.3–0.4 mm. Rare.

Our specimens are only about half the size of the one from the Velasco shale of northern Mexico.

FAMILY LITUOLIDAE REUSS, 1861

GENUS CYCLAMMINA BRADY, 1876

CYCLAMMINA PUSILLA BRADY

Plate 37, figure 7

Cyclammina pusilla Brady, *1881,* Quart. Jour. Micr. Soc., vol. 21, p. 53. (Recent).; *1884,* Rep. Voy. *Challenger,* Zool., vol. 9, p. 353, pl. 37, figs. 20-23. (Recent).

Haplophragmoides sp. White, *1929,* Jour. Pal., vol. 2, no. 4, p. 307, pl. 41, fig. 14. (Upper Cretaceous).

Test involute, nearly bilaterally symmetrical, compressed, elliptical in face view; biumbilicate; periphery angled; chambers about eleven; sutures outlined by clear shell material, not very distinct; wall finely arenaceous; aperture a curved slit at the base of the septal face on the inner periphery. Diameter, 0.43–0.55 mm.; thickness, 0.14–0.16 mm. Rare.

Our specimens were compressed by the enclosing shale and silicified, so that the structure is obscure.

FAMILY ATAXOPHRAGMIIDAE SCHWAGER, 1877

GENUS GAUDRYINA D'ORBIGNY, 1839

GAUDRYINA INDENTATA CUSHMAN AND JARVIS

Plate 37, figure 8

Gaudryina indentata Cushman and Jarvis, *1928*, Contr. Cushman Lab. Foram. Res., vol. 4, pt. 4, p. 92, pl. 13, fig. 7. (Cretaceous).

Test somewhat elongate, tapering, about three-fourths as broad as long, with bent axis; chambers depressed, indented laterally, numerous; sutures raised; wall finely arenaceous; surface smooth, apertural end depressed; aperture semicircular, at the base of the inner margin of the last-formed chamber. Length, 0.5-0.6 mm; breadth, 0.4–0.45 mm. Rare.

GENUS CLAVULINA D'ORBIGNY, 1826

CLAVULINA AMORPHA CUSHMAN

Plate 37, figure 9

Clavulina amorpha Cushman, *1926*, Bull. Am. Assn. Petroleum Geol., vol. 10, no. 6, p. 589, pl. 17, fig. 5. (Upper Cretaceous).

Test elongate, short, robust, triserial portion inflated, uniserial portion cylindrical and of smaller diameter than the triserial portion; chambers few, slightly inflated, shorter than broad; sutures slightly depressed, very obscure; wall very coarsely arenaceous, with calcareous cement; surface somewhat rough; aperture terminal, round, central, with raised lip. Length, 0.8 mm; breadth, 0.4 mm. Rare.

FAMILY TEXTULARIIDAE D'ORBIGNY, 1846

GENUS SPIROPLECTAMMINA CUSHMAN, 1927

SPIROPLECTAMMINA BENTONENSIS CARMAN

Plate 37, figure 11

Spiroplectammina bentonensis Carman, *1929*, Jour. Pal., vol. 3, no. 3, p. 311, pl. 34, figs. 8-9. (Cretaceous).

Test elongate, oval, gradually tapering from the bluntly rounded apical end; chambers planispirally coiled in the early portion, consisting of five or six chambers, the later biserial portion with about

six pairs of inflated chambers; wall coarsely arenaceous; surface rough; aperture obscure. Length, 0.42–0.7 mm. Abundant.

All of the specimens have been flattened or otherwise distorted. This form has a smaller coiled stage than *Spiroplectammina rosula* (Ehrenberg) and *S. biformis* (Parker and Jones), and is not as compressed as *S. rosula* (Ehrenberg) and *S. scotti* Cushman and Alexander.

SPIROPLECTAMMINA ROSULA (EHRENBERG)

Spiroplecta rosula Ehrenberg, *1854*, Mikrogeologie, p. 32, pl. 2, fig. 26. (Upper Cretaceous, Middle North America).—Cushman, *1927*, Jour. Pal., vol. 1, no. 3, pl. 36, fig. 26.
Spiroplectoides rosula Cushman, *1927*, Contr. Cushman Lab. Foram. Res., vol. 3, pt. 1, p. 62, pl. 13, fig. 9; *1927*, vol. 3, pt. 2, p. 114, pl. 23, figs. 6-7. (Upper Cretaceous).
Spiroplectoides clotho Cushman and Jarvis, *1928*, Contr. Cushman Lab. Foram. Res., vol. 4, pt. 4, p. 101, pl. 14, fig. 13 (but not fig. 14). (Cretaceous).

Test elongate, flattened, tapering from the broad apical end, or with edges parallel, and with low ridge down the middle of each side; chambers five or six in the early coiled part, very narrow and angled in the biserial portion which consists of seven to nine pairs of chambers; periphery sharp with narrow keel; sutures slightly raised, transparent; wall finely arenaceous, with siliceous cement, and translucent; surface somewhat rough and granular; aperture obscure. Length, 0.35–0.5 mm. Common.

The wall is now entirely siliceous, the surface is rough and granular, and there is little doubt that the wall was originally arenaceous.

GENUS TEXTULARIA DEFRANCE, 1824

TEXTULARIA MEXICANA CUSHMAN

Plate 37, figure 12

Textularia mexicana Cushman, *1922*, U. S. Nat. Mus. Bull. 104, pt. 3, p. 17, pl. 2, fig. 9. (Recent).
Textularia carinata Flint (not d'Orbigny), *1897 (1899)*, Rep. U. S. Nat. Mus., p. 284, pl. 29, fig. 1. (Recent).

Test cuneiform, with strong, rounded median ridge and concave lateral slopes, rhomboidal in cross section; edges sharp and irregularly serrate; chambers about nine pairs, very much broader than long; sutures elevated, nearly straight; wall finely arenaceous with an occasional larger grain, thin between the raised sutures, and appearing darker than the sutures; aperture an elongate slit at right angles to the plane of flattening, about a third as long as the width of the septal face. Length, 0.42-0.7 mm. Common.

The concave lateral slopes, wide flange and less curved sutures distinguish this species from *T. flabelliformis* Gümbel. It is shorter and lacks the regular spines of *T. pseudocarinata* Cushman. It differs from *T. mississippiensis* Cushman in the concave later slopes.

FAMILY NODOSARIIDAE SCHULTZE, 1854

GENUS PSECADIUM NEUGEBOREN, 1856

PSECADIUM ADUNCUM (COSTA)

Plate 37, figure 13

Glandulina adunca Costa, *1856,* Atti. Accad. Pontiana, vol. 7, fasc., p. 128, pl. 11, fig. 24. (Pliocene).

Test short, fusiform, round in section, the early chambers coiled in about half a whorl, showing the planispiral ancestry; chambers four to six, rapidly enlarging, the last-formed one constituting three-fourths of the test; sutures flush, distinct; surface smooth; aperture terminal, produced, round, radiate. Length, 0.32 mm. Rare.

This form is intermediate between *Marginulina* and *Glandulina,* and is usually considered as the microspheric form of *Glandulina laevigata* d'Orbigny. It shows that *Glandulina* was derived from a planispiral form rather than from a polymorphine one.

GENUS OOLINA D'ORBIGNY, 1839

OOLINA INORNATA D'ORBIGNY

Plate 37, figure 14

Oolina inornata d'Orbigny, *1839,* Voy. Amér. Mérid., vol. 5, pt. 5, p. 21, pl. 5, fig. 13. (Recent).

Lagena inornata Reuss, *1862,* Sitz. k. Ak. Wiss. Wien, Math.-Naturw. Cl., vol. 46, pt. 1, p. 320, pl. 1, fig. 12. (Oligocene-Miocene).

Test citriform, surface smooth; wall very finely perforate; aperture round, terminal, with slight lip. Length, 0.2 mm. Rare.

GENUS DENTALINA D'ORBIGNY, 1839

DENTALINA BÖTTCHERI REUSS

Plate 37, figure 16

Dentalina böttcheri Reuss, *1863 (1864),* Sitz. k. Ak. Wiss. Wien, Math.-Naturw. Cl., vol. 48, pt. 1, p. 45, pl. 2, fig. 17. (Middle Oligocene).

Test elongate, slightly curved, round in cross section; chambers ten, gradually enlarging, early ones closely appressed and cylindrical;

later ones bulbous; sutures oblique, narrow; surface smooth; aperture protruding, round, radiate, near the concave side of the test. Length, 1.25 mm. Abundant.

Genus NODOSARIA Lamarck, 1812

NODOSARIA ARUNDINEA Schwager

Plate 37, figure 15

Nodosaria arundinea Schwager, *1866*, *Novara*-Exped., Geol. Theil, vol. 2, p. 211, pl. 5, figs. 43-45. (Pliocene).—Sherborn and Chapman, *1866*, Jour. Roy. Micr. Soc., ser. 2, vol. 6, p. 747, pl. 14, figs. 28-29. (Lower Eocene).—Cushman and Hanna, *1927*, Proc. Calif. Acad. Sci., ser. 4, vol. 16, no. 8, p. 215, pl. 13, fig. 14. (Eocene).—Galloway and Morrey, *1929*, Bull. Am. Pal., vol. 15, no. 55, p. 16, pl. 1, fig. 15. (Upper Eocene).
Nodosaria calamus Silvestri, *1872*, Atti Accad. Gioenia Sci. Nat. Catania, ser. 3, vol. 7, p. 87, pl. 10, figs. 243-251. (Pliocene).

Test slender, very elongate, straight, subcylindrical; chambers two to three times as long as broad, probably numerous though no complete specimens were found; sutures indistinct, somewhat depressed; surface smooth; aperture round, probably radiate, indistinct in our specimens. Length, of broken specimen 1.38 mm. Common.

NODOSARIA CONSOBRINA (d'Orbigny)

Plate 37, figure 17

Dentalina consobrina d'Orbigny, *1846*, Foram. Foss. Bass. Tert. Vienne, p. 46, pl. 2, figs. 1-2. (Miocene).—Cushman and Hanna, *1927*, Proc. Calif. Acad. Sci., ser. 4, vol. 16, no. 8, p. 214, pl. 13, figs. 12-13. (Eocene).—Cushman, *1929*, Contr. Cushman Lab. Foram. Res., vol. 5, pt. 4, p. 86, pl. 12, fig. 29.
Nodosaria consobrina Galloway and Morrey, *1929*, Bull. Am. Pal., vol. 15, no. 55, p. 15, pl. 1, fig. 13. (Eocene).

Test elongate, slender, slightly curved, with an apical spine; chambers four in a broken specimen, increasing in size, the later ones twice as long as broad; sutures distinct, constricted, not oblique; surface smooth; aperture round, radiate. Length, 0.85 mm. Rare.

NODOSARIA LEPIDULA Schwager

Plate 38, figure 1

Nodosaria lepidula Schwager, *1866*, Novara-Exped., Geol. Theil, vol. 2, p. 210, pl. 5, figs. 27-28. (Pliocene).—Galloway and Morrey, *1929*, Bull. Am. Pal., vol. 15, no. 55, p. 17, pl. 2, fig. 2. (Eocene.)

Test elongate, straight, gradually tapering; chambers globular, six in a broken specimen, the earlier ones with angulate and fimbriate lower edge; sutures very much constricted; surface smooth, granular; aperture large, round, terminal. Length, 0.6 mm. Rare.

NODOSARIA RUDIS D'ORBIGNY
Plate 38, figure 2

Nodosaria rudis d'Orbigny, *1846,* Foram. Foss. Bass. Tert. Vienne, p. 33, pl. 1, figs. 17-19. (Miocene).

Test elongate, straight; chambers globular, three in a broken specimen, separated by long, thick necks, giving a strangulated appearance; surface smooth, granular in calcified specimens; aperture terminal, round. Length of broken specimens up to 0.68 mm. Common.

The necks in the Tabasco specimens are thicker than those in d'Orbigny's figure.

NODOSARIA SPINESCENS (REUSS)
Plate 38, figure 3

Dentalina spinescens Reuss, *1851,* Zeitschr. deutsch. geol. Gesell., vol. 3, p. 62, pl. 3, fig. 10. (Middle Oligocene).
Nodosaria spinescens Plummer, *1926 (1927),* Univ. Texas, Bull. 2644, p. 84, pl. 4, fig. 12. (Eocene).

Test elongate, slender, gradually enlarging; chambers twice as long as wide, three in a broken specimen; sutures constricted, not

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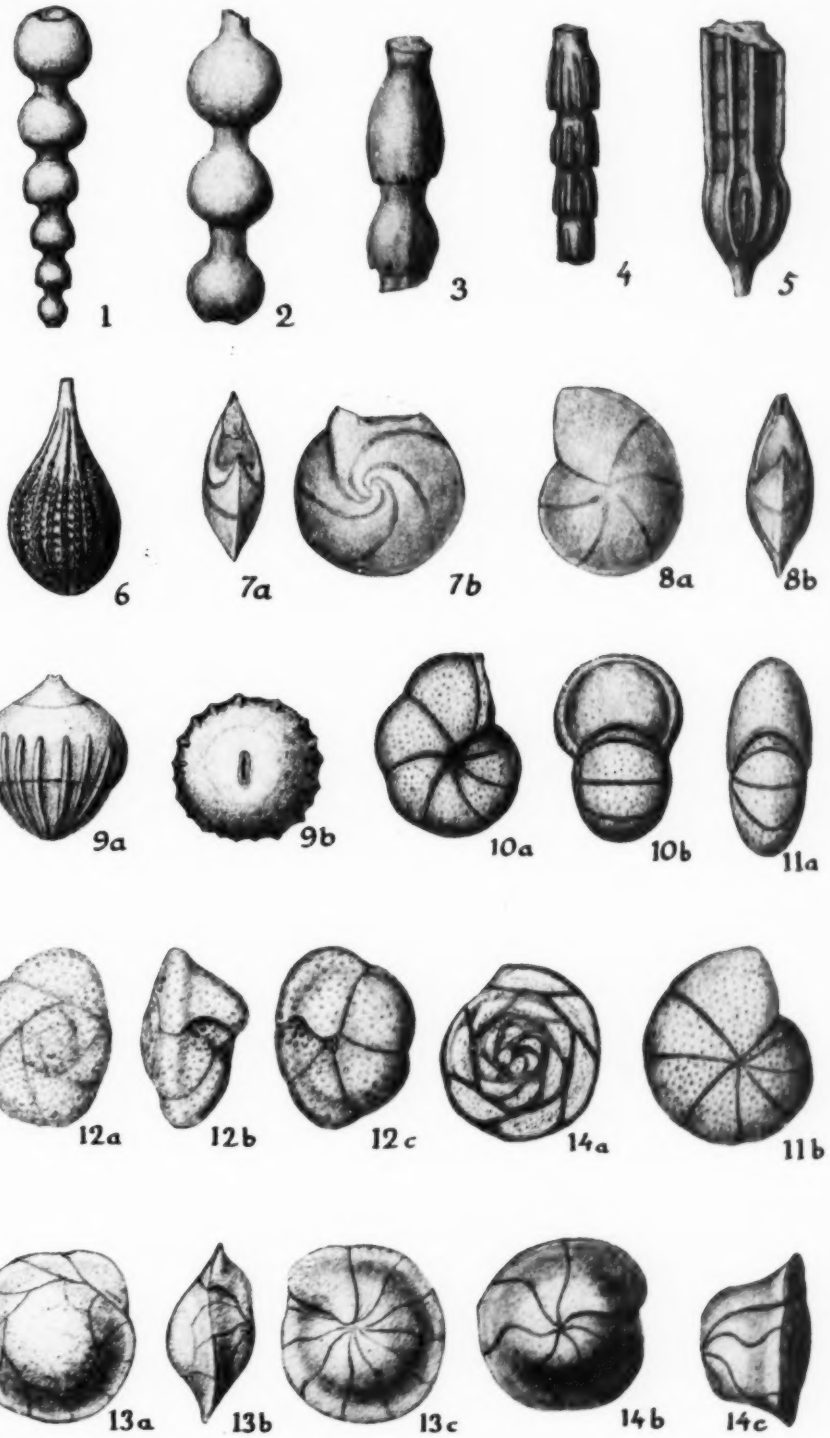
EXPLANATION OF PLATE 38

FIGS. 1—*Nodosaria lepidula* Schwager, × 70. (p. 337)
2—*Nodosaria rudis* d'Orbigny, × 60. (p. 338)
3—*Nodosaria spinescens* (Reuss), × 85. (p. 338)
4—*Nodosaria spinosa* (d'Orbigny), × 40. (p. 339)
5—*Nodosaria vertebralis* (Batsch), × 50. (p. 339)
6—*Lagena torquata* Brady, × 80. (p. 339)
7*a, b*—*Robulus curvisepta* (Seguenza), × 55. *a,* Edge view; *a,* Side view. (p. 340)
8*a, b*—*Robulus incompta* (Reuss), × 75. *a,* Side view; *b,* Edge view. (p. 340)
9*a, b*—*Gonatosphaera multicostata* (Costa), × 90. *a,* Side view; *b,* Apertural view. (p. 340)
10*a, b*—*Nonion pompilioides* (Fichtel and Moll), × 90. *a,* Side view; *b,* Apertural view. (p. 341)
11*a, b*—*Pullenia puentapiedraensis* Galloway and Morrey, n. sp., × 105. *a,* Apertural view; *b,* Side view. (p. 341)
12*a-c*—*Globorotalia crassula* (Cushman and R. E. Stewart), × 90. *a,* Dorsal view; *b,* Edge view; *c,* Ventral view. (p. 342)
13*a-c*—*Rotalia puscatanensis* Galloway and Morrey, n. sp., × 100. *a,* Dorsal view; *b,* Edge view; *c,* Ventral view. (p. 342)
14*a-c*—*Gyroidina florealis* White, × 60. *a,* Dorsal view; *b,* Ventral view; *c,* Edge view. (p. 342)



Galloway and Morrey, Cretaceous Foraminifera

oblique; surface smooth except for two annuli of spines on the lower third of each chamber; aperture small, round, central, doubtfully radiate. Length, 0.4 mm. Rare.

Our specimens are exactly like those of Plummer's. The chambers are longer than those shown in Reuss's figures.

NODOSARIA SPINOSA (D'ORBIGNY)

Plate 38, figure 4

Dentalina spinosa d'Orbigny, *1846*, Foram. Foss. Bass. Tert. Vienne, p. 55, pl. 2, figs. 36-37. (Miocene).—Cushman, *1929*, Contr. Cushman Lab. Foram. Res., vol. 5, pt. 4, p. 86, pl. 13, figs. 7-8. (Miocene).

Test elongate, straight; chambers somewhat inflated, four in a broken specimen; sutures depressed; surface covered with eight to ten prominent, sharp costae which are not continuous beyond the suture lines of each chamber; aperture small, round, terminal. Length, 0.75 mm. Rare.

NODOSARIA SPINOSA (D'ORBIGNY)

Plate 38, figure 5

Nautilus vertebralis Batsch, *1791*, Conch. Seesands, pl. 2, fig. 6 a-b. (Recent).

Nodosaria vertebralis Brady, *1884*, Rep. Voy. *Challenger*, Zool., vol. 9, p. 514, pl. 63, fig. 35; pl. 64, figs. 11-14. (Recent).—Cushman, *1923*, U. S. Geol. Surv., P.P. 133, p. 27, pl. 4, fig. 1. (Lower Oligocene).—Plummer, *1926 (1927)*, Univ. Texas, Bull. 2644, p. 88, pl. 5, fig. 10. (Eocene).—Galloway and Morrey, *1929*, Bull. Am. Pal., vol. 15, no. 55, p. 14, pl. 1, fig. 10. (Upper Eocene).

Nodosaria obliqua Cushman, *1921* U. S. Geol.Surv., P.P. 129 F, p. 129, pl. 30, fig. 6. (Eocene to Recent).

Test elongate, tapering, slightly curved, with an apical spine; chambers numerous, four in a broken specimen, broader than long, the initial chamber bulbous; sutures limbate; surface ornamented with eight or more prominent, coarse, longitudinal costae, some of which are intercalated in the initial chamber; aperture medium, round. Length of figured specimen, 0.72 mm. Rare.

GENUS LAGENA WALKER AND BOYS, 1784

LAGENA TORQUATA BRADY

Plate 38, figure 6

Lagena torquata Brady, *1881*, Quart. Jour. Micr. Sci., vol. 2, p. 62; *1884*, Rep. Voy. *Challenger*, Zool., vol. 9, p. 469, pl. 58, fig. 41. (Recent).—Cushman, *1913*, U. S. Nat. Mus., Bull. 71, pt. 3, p. 27, pl. 11, fig. 3. (Recent).

Test bulbous, elongate, with long, tapering neck; surface ornamented with about twenty-four longitudinal costae; alternate costae extend the length of the test and those in between extend from the apical end for about two-thirds the length of the test; a row of pits extends along the top of each costa; cross lines between the costae give a reticulate appearance to the surface; aperture round, at the end of a long, tapering neck. Length, 0.34 mm. Rare.

Our specimen does not show the small apical spine that Brady's has.

Genus ROBULUS Montfort, 1808

ROBULUS CURVISEPTA (Seguenza)

Plate 38, figure 7

Robulina curvisepta Seguenza, *1880*, Atti. R. Accad. Lincei, ser. 3, vol. 6, p. 124, pl. 13, fig. 20a. (Middle Miocene).

Test discoidal, biconvex; periphery angled; chambers about five in the last whorl; sutures strongly curved, limbate, flush, of clear shell material; surface smooth; aperture a very narrow slit, vaguely radiate. Diameter, 0.4–0.75 mm. Rare.

ROBULUS INCOMPTA (Reuss)

Plate 38, figure 8

Robulina incompta Reuss, *1851*, Zeitschr. deutsch. geol. Gesell., vol. 3, p. 70, pl. 4, fig. 28. (Middle Oligocene).

Test ovate, biconvex; periphery keeled; chambers about six, gradually increasing in size, the last one somewhat drawn out; sutures flush, limbate; surface smooth; aperture narrow, finely radiate on the outer margin. Diameter, 0.35–0.5 mm. Common.

Genus GONATOSPHAERA Guppy, 1894

GONATOSPHAERA MULTICOSTATA (Costa)

Plate 38, figure 9

Lingulina multicostata Costa, *1855-1857*, Mem. Reale Accad. Sci. Mat., Sci. Natur. Sci. Mor. Cl., vol. 2, (Napoli, 1857), p. 146, pl. 2, fig. 6. (Upper Miocene).—Fornasini, *1897*, Rendi. Sess. R. Accad. Sci. Instit. Bologna, n. ser., vol. 1, p. 120, fasc. 3, figs. 1-7. (Pliocene).

Test bulbous, somewhat longer than broad, consisting of two chambers; surface provided with about twenty distinct costae which extend from the apical end and disappear towards the apertural end,

leaving the last third of the test smooth; aperture fissurine, terminal, central, with raised lip. Diameter, 0.22 mm. Rare.

FAMILY NONIONIDAE REUSS, 1860

GENUS NONION MONTFORT, 1808

NONION POMPILIOIDES (FICHTEL AND MOLL)

Plate 38, figure 10

Nautilus pompilioides Fichtel and Moll, *1798,* Test. Micr., p. 31, pl. 2, figs. a-c. (Pliocene—Recent).
Nonionina pompilioides Brady, *1884,* Rep. Voy. Challenger, Zool., vol. 9, p. 727, pl. 109, figs. 10-11. (Recent).
Nonion umbilicatulus Cushman and Schenck, *1928,* Univ. Calif. Pub. Bull. Dept. Geol. Sci., vol. 17, no. 9, p. 310, pl. 44, fig. 2. (Lower Oligocene).
Nonion pompilioides Galloway and Morrey, *1929,* Bull. Am. Pal., vol. 15, no. 55, p. 43, pl. 6, fig. 15. (Upper Eocene).—Cushman, *1929,* Contr. Cushman Lab. Foram. Res., vol. 5, pt. 4, p. 89, pl. 13, fig. 25. (Miocene).

Test bilaterally symmetrical, subcircular in side view, oval in face view, with small umbilicus; axial diameter increasing slowly; chambers six to seven in the last whorl; sutures distinct, slightly curved, of clear shell material, very little depressed; wall conspicuously perforate; aperture a long narrow slit on the inner margin of the last septal face. Diameter, 0.3 mm.; thickness, 0.22mm. Rare.

Our specimens have fewer chambers and the sutures are more curved and deeper in the later part of the last whorl than as shown in Fichtel and Moll's figures.

GENUS PULLENIA PARKER AND JONES, 1862

PULLENIA PUENTEPIEDRAENSIS GALLOWAY AND MORREY, N. SP.

Plate 38, figure 11

Test bilaterally symmetrical, somewhat flattened; whorls embracing to umbilicus; chambers seven to eight in the last whorl; sutures distinct, very little depressed, nearly straight, limbate, of clear shell material; wall conspicuously perforate; aperture a narrow slit on the inner margin of the last septal face. Diameter, 0.25 mm.; thickness, 0.15 mm. Rare.

This species differs from *P. salisburyi* Stewart and Stewart, which it closely resembles, in the larger number of chambers, less curved sutures and coarser perforations.

FAMILY ROTALIIDAE REUSS, 1861

GENUS GLOBOROTALIA CUSHMAN, 1929

GLOBOROTALIA CRASSULA (CUSHMAN AND R. E. STEWART)
Plate 38, figure 12

Globigerina crassula Cushman and R. E. Stewart, *1930*, Trans. San Diego Soc. Nat. Hist., vol. 6, no. 2, p. 77, pl. 7, fig. 1. (Pliocene).

Test rotaloid, dorsal side nearly flat, ventral side very convex, slightly umbilicate; periphery with prominent shoulder, but not sharply angulate, slightly lobate; chambers four to four and a half in the last whorl, moderately appressed; sutures shallow, oblique on the dorsal side, radial on the ventral side; entire surface strongly papillate, coarser to the rear of the aperture; the inner part of the spire obscure; aperture a narrow slit extending from the umbilicus nearly to the periphery, without definite lip. Diameter, 0.26 mm. Common.

This species has more closely appressed chambers than the similar *Globigerina crassaformis* Galloway and Wissler. It lacks the sharply angled periphery of *Globigerina angulata* White.

GENUS ROTALIA LAMARCK, 1804

ROTALIA PUSCATANENSIS GALLOWAY AND MORREY, N. SP.
Plate 38, figure 13

Test discoidal, thick, unequally biconvex, the dorsal side more so, ventral side umbonate; periphery not lobulate; peripheral margin acute, with prominent keel; chambers about ten in the last whorl; sutures indistinct, nearly flush, curved and tangential on the dorsal side, curved and nearly radial on the ventral side; wall finely perforate; surface smooth; aperture a narrow slit near the periphery at the base of the last septal face. Diameter, 0.25–0.38 mm. Common.

This species differs from *R. nana* (Reuss) in having more chambers in the last whorl, a less lobulate periphery, and in lacking the umbo.

GENUS GYROIDINA D'ORBIGNY, 1826

GYROIDINA FLOREALIS WHITE
Plate 38, figure 14

Gyroidina florealis White, *1928*, Jour. Pal., vol. 2, no. 4, p. 293, pl. 40, fig. 3. (Upper Cretaceous).

Test plano-convex; dorsal side nearly flat, ventral side strongly convex; periphery sharply angled, with a broad keel; chambers six to seven in the last whorl; sutures on the dorsal side limbate, curved and flush; on the ventral side radial, slightly curved, less distinct than those on the dorsal side; wall very finely perforate; surface smooth; aperture an elongate slit on the inner margin of the last chamber, near the periphery. Diameter, 0.2–0.3 mm; thickness, 0.15–0.2 mm. Common.

The Tabasco specimens are much smaller than White's types, and are wider at the base of the ventral side.

GYROIDINA SOLDANII OCTOCAMERATA Cushman and Hanna

Plate 39, figure 1

Gyroidina soldanii octocamerata Cushman and Marcus Hanna, *1927*, Trans. San Diego Soc. Nat. Hist., vol. 5, no. 4, dated March 15, 1927, p. 56, pl. 5, fig. 7. (Eocene).—Cushman and G. D. Hanna, Proc. Calif. Acad. Sci., ser. 4, vol. 16, dated April 22, 1927, p. 223, pl. 14, figs. 16-18. (Eocene).

Test unequally biconvex, the ventral side more so, with small umbilicus; spire obscure; peripheral margin broadly rounded; chambers seven to eight in the last whorl; sutures slightly depressed, curved on the dorsal side, nearly straight on the ventral side; wall finely perforate; surface smooth; aperture a narrow slit at the base of the septum, extending from the umbilicus to the dorsal side of the test. Diameter, 0.32 mm. Rare.

Genus DISCORBIS Lamarck, 1804

DISCORBIS INFLATA (Reuss)

Plate 39, figure 2

Rosalina inflata Reuss, *1862 (1863)*, Sitz. k. Ak. Wiss. Wien, Math.-Naturw. Cl., vol. 46, pt. 1, p. 87, pl. 11, fig. 6. (Cretaceous).
Discorbina inflata Egger, *1907-1909 (1910)*, Berichte Naturw. Ver. Regensburg, vol. 12, p. 86, pl. 3, figs. 4-6. (Cretaceous).

Test unequally biconvex, the dorsal side slightly more convex, ventral side umbilicate, peripheral margin broadly rounded; chambers five to five and one-half in the last whorl, rapidly enlarging; sutures much curved, depressed, not limbate; wall coarsely perforate; aperture on the ventral side of the base of the last chamber, extending from the umbilicus to the periphery, with slight lip. Diameter, 0.3–0.35 mm; thickness, 0.16–0.22 mm. Rare.

DISCORBIS TABASCOENSIS GALLOWAY AND MORREY, N. SP.
Plate 39, figure 3

Test biconvex, the dorsal side with a large umbo, ventral side umbilicate; peripheral margin broadly rounded; chambers numerous, six or seven in the last whorl; sutures depressed and slightly curved, the later ones obscurely crenulate, especially near the umbo and umbilicus; wall coarsely perforate; aperture a curved slit at the base of the last chamber at one side of the periphery and extending on the ventral side to the umbilicus. Diameter, 0.3 mm; thickness, 0.14 mm. Rare.

This form would be included under *Anomalina* by many authors, but the aperture is on the ventral, not on the dorsal side, as in the type of *Anomalina.*

EXPLANATION OF PLATE 39

FIGS. 1*a-c*—*Gyroidina soldanii octocamerata* Cushman and G. D. Hanna, × 75. *a*, Dorsal view; *b*, Edge view; *c*, Ventral view. (p. 343)

2*a-c*—*Discorbis inflata* (Reuss), × 90. *a*, Dorsal view; *b*, Ventral view; *c*, Edge view. (p. 343)

3*a-c*—*Discorbis tabascoensis* Galloway and Morrey, n. sp., × 90. *a*, Dorsal view; *b*, Edge view; *c*, Ventral view. (p. 344)

4*a-c*—*Cibicides dekayi* (Reuss), × 40. *a*, Ventral view; *b*, Edge view; *c*, Dorsal view. (p. 345)

5*a-c*—*Cibicides cognatus* Galloway and Morrey, n. sp., × 70. *a*, Dorsal view; *b*, Ventral view; *c*, Edge view. (p. 345)

6*a-c*—*Cibicides pachyderma* (Rzehak), × 50. *a*, Ventral view; *b*, Dorsal view; *c*, Edge view. (p. 345)

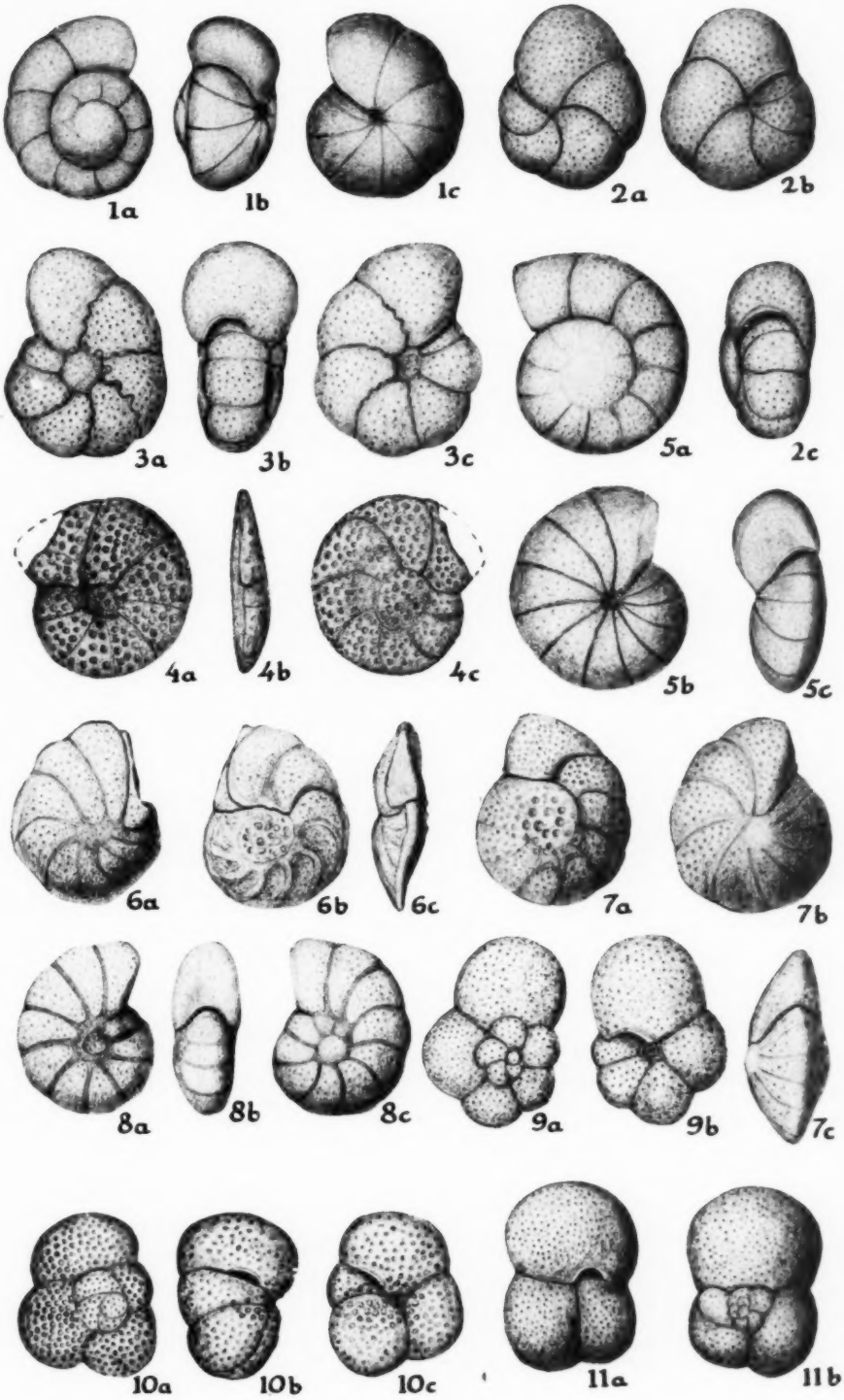
7*a-c*—*Cibicides spiropunctatus* Galloway and Morrey, n. sp., × 35. *a*, Dorsal view; *b*, Ventral view; *c*, Edge view. (p. 346)

8*a-c*—*Planulina scrobiculata* (Schwager), × 130. *a*, Ventral view; *b*, Edge view; *c*, Dorsal view. (p. 346)

9*a*, *b*—*Globigerina pseudobulloides* Plummer, × 90. *a*, Dorsal view; *b*, Ventral view. (p. 347)

10*a-c*—*Globigerina asperula* Gümbel, × 65. *a*, Dorsal view; *b*, Edge view; *c*, Ventral view. (p. 347)

11*a*, *b*—*Globigerina triloculinoides* Plummer, × 75. *a*, Ventral view; *b*, Dorsal view. (p. 348)



Galloway and Morrey, Cretaceous Foraminifera

GENUS CIBICIDES MONTFORT, 1808

CIBICIDES COGNATUS GALLOWAY AND MORREY, N. SP.

Plate 39, figure 5

Test biconvex, dorsal side low; ventral side deep and umbilicate; periphery rounded; chambers ten to twelve in the last whorl; sutures limbate, flush with the surface, slightly curved both dorsally and ventrally; wall coarsely perforate, mural pores obscure; surface smooth, with secondary thickening on the dorsal side; aperture narrow, extending along the dorsal side for a distance of one chamber. Diameter, 0.15–0.39 mm; thickness, 0.1–0.2 mm. Abundant.

This species resembles *"Rotalina" polyraphes* Reuss, but our specimens are not as flat on the dorsal side as that shown in Reuss' figure. This species also resembles *Rotalia beccariiformis* White, but lacks the beads near the umbilicus and has coarse perforations. It is similar to *Rotalia cretacea* Carsey, but the chambers are not inflated. This form does resemble some species of *Rotalia,* but the coarse pores and the aperture continuing on the dorsal side place it properly in *Cibicides.* It differs from *Rotalina crenata* Reuss in the less inflated chambers, smaller umbilicus, and smoother dorsal side.

CIBICIDES DEKAYI (REUSS)

Plate 39, figure 4

Truncatulina Dekayi Reuss, *1861 (1862),* Sitz. Ak. Wiss. Math.-Naturw. Cl. Wien, vol. 44, pt. 1, p. 338, pl. 7, fig. 6. (Upper Cretaceous, N.J.).

Test subcircular, very much compressed; dorsal side slightly concave; ventral side slightly convex and umbilicate; peripheral margin acutely rounded; chambers eight or nine in the last whorl; sutures indistinct, depressed, curved, not limbate; wall coarsely perforate with very large pits on both sides of the test; aperture a narrow slit on the periphery, extending on the dorsal side for a distance of one chamber. Length, 0.62 mm; breadth, 0.47 mm; thickness, 0.12 mm. Rare.

Our specimens are imperfect and crushed.

CIBICIDES PACHYDERMA (RZEHAK)

Plate 39, figure 6

Truncatulina pachyderma Rzehak, *1885 (1886),* Verh. naturf. Ver Brünn, Sitz, vol. 24, p. 87, pl. 1, fig. 5. (Miocene).

Test compressed, unequally biconvex; ventral side more convex; dorsal side with large umbo covered with knobs which tend to be ar-

ranged in a coil; peripheral margin sharp, keeled; periphery slightly lobulate; chambers ten to twelve in the last whorl; sutures limbate, depressed in the later part of the last whorl, raised in the earlier part on the dorsal side, depressed on the ventral side, slightly curved, more so on the dorsal side; wall coarsely perforate with thickening over the spire on the dorsal side, which reduces the number of mural pores and enlarges those remaining, less coarse on the ventral side; aperture narrow, at the base of the last chamber, on the periphery with raised lip, and extending along the suture line on the dorsal side for a distance of two or three chambers. Diameter, 0.2–0.5 mm; thickness, 0.09–0.16 mm. Abundant.

CIBICIDES SPIROPUNCTATUS GALLOWAY AND MORREY, N. SP.
Plate 39, figure 7

Test discoidal, involute on the ventral side with large umbo of clear shell material, partially involute on the dorsal side; the ventral side more convex than the dorsal; periphery scarcely at all lobulate except the outside of the last two or three chambers; peripheral margin bluntly angled; chambers ten to twelve in the last whorl; sutures slightly curved, limbate and raised on the dorsal side, the sutures between the whorls raised into a spiral line, and fused with thickening covering the spire around which there is a row of small depressions; sutures on the ventral side slightly curved, more so toward the outer ends, raised in the earlier part of the last whorl, depressed in the later part; wall coarsely perforate, aperture on the periphery, with outer lip, and extending along the suture between the last two whorls on the dorsal side for a distance of three or four chambers. Diameter, 0.3–0.7 mm; thickness, 0.2–0.35 mm. Abundant.

GENUS PLANULINA D'ORBIGNY, 1826

PLANULINA SCROBICULATA (SCHWAGER)
Plate 39, figure 8

Anomalina scrobiculata Schwager, *1883*, Paleontographica, vol. 30, Pal. Theil, p. 129, pl. 29, (pl. 6), fig. 18 a-d. (Eocene).

Test unequally biconvex, dorsal side flattened, ventral side convex, involute, umbilicate; the last whorl tends to embrace the spire on the dorsal side; periphery rounded; chambers nine to ten in the last whorl; sutures slightly curved, limbate, of clear shell material; wall hyaline, coarsely perforate; aperture at the base of the septum, ex-

tending a slight distance on both sides of the test. Length, 0.24 mm; breadth, 0.16 mm. Rare.

FAMILY GLOBIGERINIDAE CARPENTER, 1862

GENUS GLOBIGERINA D'ORBIGNY, 1826

GLOBIGERINA ASPERULA GÜMBEL

Plate 39, figure 10

Globigerina asperula Gümbel, *1868 (1870)*, Abh.k. bay. Wiss., München, Math.-Phys. Cl., vol. 10, p. 661, pl. 2, fig. 108. (Eocene).

Test subglobular, nearly as broad as long, rotaloid, spire low: ventral side deep; chambers fairly closely appressed, four in the last whorl; sutures moderately deep; surface reticulate, coarsely granulate around the umbilical region; aperture a small arch at the base of the last septal face, about midway between the umbilicus and the periphery. Diameter, 0.34 mm.

This species resembles *G. spirata* Bornemann, but is somewhat thicker dorso-ventrally and is not smooth and polished.

GLOBIGERINA PSEUDOBULLOIDES PLUMMER

Plate 39, figure 9

Globigerina pseudobulloides, Plummer, *1926 (1927)*, Univ. Texas, Bull. 2644, p. 133, pl. 8, fig. 9. (Lower Eocene).—Galloway and Morrey, *1929*, Bull. Am. Pal., vol. 15, no. 55, p. 10, pl. 3, fig. 8. (Eocene).

Test low-spired with small umbilicus on the ventral side; chambers inflated, rapidly enlarging, five in the last whorl; sutures deep; wall coarsely perforate; surface finely reticulate; aperture a low arch, extending from the umbilicus nearly to the periphery, with slight lip. There are no dorsal apertures. Diameter, 0.22–0.31 mm. Abundant.

This species differs from *G. bulloides* d'Orbigny, as illustrated in his Model no. 76, and as commonly understood, in having five instead of four chambers in the last whorl, and in having a smaller aperture not confined to the umbilicus. The chambers are a little more closely appressed than they are in the Texas Eocene type of the species. This species differs from *G. dutertrei* d'Orbigny in being oval in shape, rather than round, and the last chamber is relatively smaller. About half the specimens are dextral and half sinistral.

GLOBIGERINA TRILOCULINOIDES PLUMMER

Plate 39, figure 11

Globigerina triloculinoides Plummer, *1926 (1927)*, Univ. Texas, Bull. 2644, p. 134, pl. 8, fig. 10. (Eocene).

Test composed of about eight or nine globular chambers, three in the last whorl, the last chamber nearly as large as the remainder of the test; sutures deep; wall coarsely perforate; aperture an arched slit at the base of the last chamber, above the umbilicus. There are no dorsal apertures. Diameter, 0.27–0.35 mm. Rare.

The chambers of *G. pseudotriloba* White are more inflated than those of this species.

GENUS ORBULINA D'ORBIGNY, 1826

ORBULINA UNIVERSA D'ORBIGNY

Plate 40, figure 1

Orbulina universa d'Orbigny, *1839*, Barker, Webb and Berthelot, Hist. Nat. Iles Canaries, vol. 2, pt. 2, Foram. p. 123, pl. 1, fig. 1. (Recent).

A typical specimen. The pores are smaller than in recent specimens. Diameter, 0.2 mm. Rare.

EXPLANATION OF PLATE 40

FIGS. 1—*Orbulina universa* d'Orbigny, × 100. (p. 348)

2*a*, *b*—*Bolivina colemani* Galloway and Morrey, n. sp., × 60. *a*, Side view; *b*, Apertural view. (p. 349)

3*a*, *b*—*Bolivina monilifera* Galloway and Morrey, n. sp., × 115. *a*, Side view; *b*, Apertural view. (p. 349)

4—*Plectofrondicularia* sp., × 75. (p. 349)

5*a*, *b*—*Turrillina trochoides* (Reuss), × 105. *a*, Side view; *b*, Apertural view. (p. 350)

6—*Bulimina callahani* Galloway and Morrey, n. sp., × 75. (p. 350)

7—*Bulimina inflata* Seguenza, × 105. (p. 351)

8, 9—*Bulimina declivis* Reuss, 8, × 65; 9, × 50. (p. 351)

10*a*, *b*—*Bulimina laevigata* d'Orbigny, × 40. *a*, Side view; *b*, Apertural view. (p. 351)

11—*Bulimina tabascoensis* Galloway and Morrey, n. sp., × 60. (p. 352)

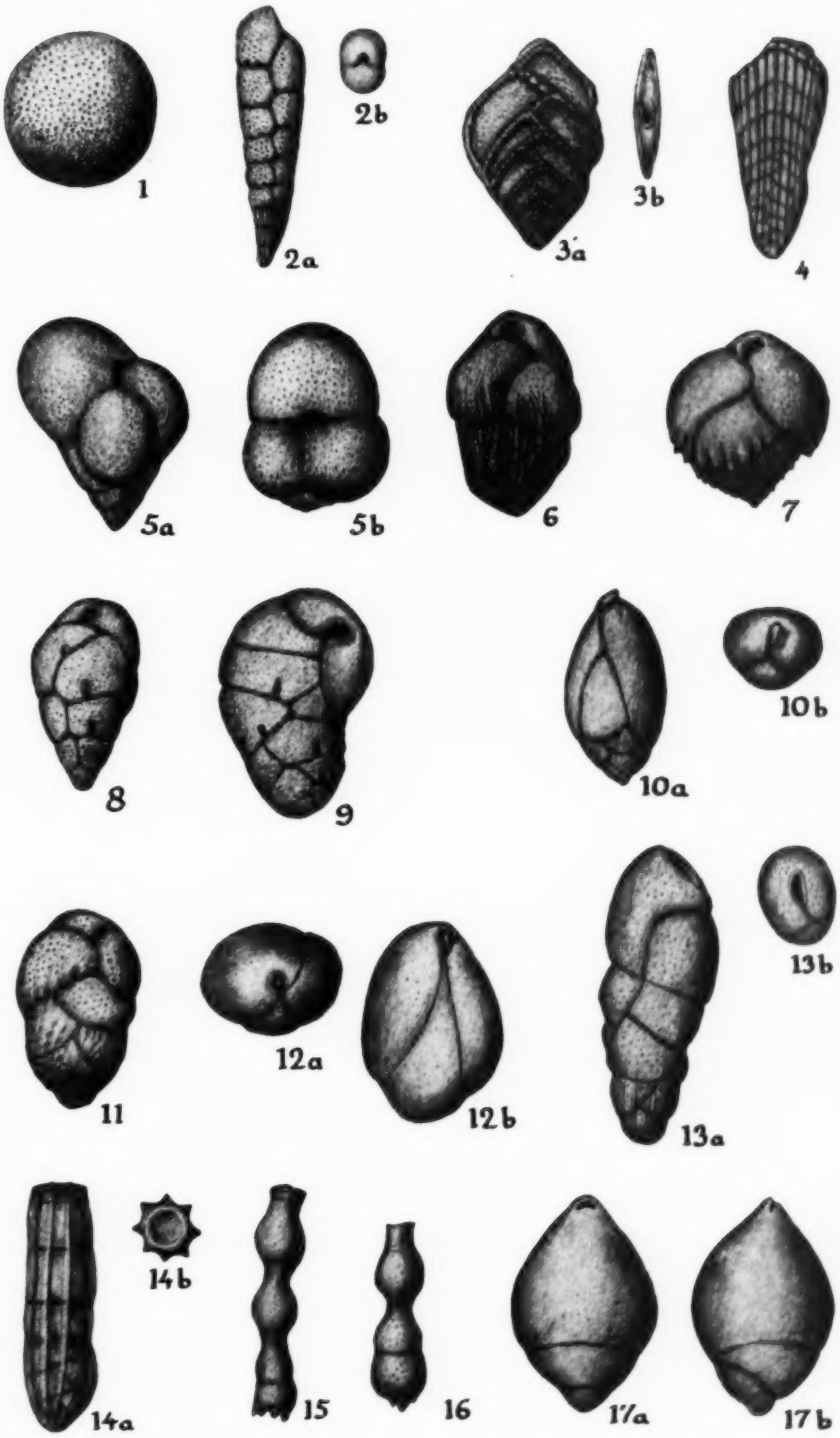
12*a*, *b*—*Globobulimina sobrina* Galloway and Morrey, n. sp., × 60. *a*, Apertural view; *b*, side view. (p. 352)

13*a*, *b*—*Virgulina mustoni* Andreae, × 130. *a*, Side view; *b*, Apertural view. (p. 353)

14*a*, *b*—*Siphogenerina digitalis* Galloway and Morrey, n. sp., × 75. *a*, Side view; *b*, End view. (p. 353)

15, 16—*Siphonodosaria abyssorum* (Brady), × 60. (p. 353)

17*a*, *b*—*Ellipsopolymorphina schlichti* (Silvestri), × 100. *a*, Front view; *b*, Side view. (p. 354)



Galloway and Morrey, Cretaceous Foraminifera

FAMILY HETEROHELICIDAE CUSHMAN, 1927

GENUS BOLIVINA D'ORBIGNY, 1839

BOLIVINA COLEMANI GALLOWAY AND MORREY, N. SP.

Plate 40, figure 2

Test elongate, slightly flattened, obtusely pointed, sides nearly parallel, edges rounded; straight or bent, and twisting through 30° to 90°; early portion with fine longitudinal costae, later portion smooth except for crenulations along the suture lines; chambers eight or nine on a side, with nearly parallel sutures, the junction between the two series only slightly zig-zagged; wall finely perforate; aperture a very small loop at the base of the last chamber. Length, 0.44–0.8 mm; breadth, 0.12–0.22 mm. Abundant.

Our species differs from *B. applinae* (Plummer) in the twisting during growth, the parallel sutures, and the junction between the two sets of chambers is only slightly zigzag. Though we have numerous specimens none of them show a uniserial portion.

BOLIVINA MONILIFERA GALLOWAY AND MORREY, N. SP.

Plate 40, figure 3

Test flabelliform, flattened, with a sharp, narrow keel of clear shell material, initial end angled; chambers six or seven on a side; sutures nearly straight, limbate, raised and beaded; wall thick, finely perforate; aperture an elongate slit. Length, 0.24 mm; breadth, 0.16 mm. Rare.

This species is similar to *B. ariana* Cole and Ponton, but differs in the shape of the chambers and in the tuberculate borders of the chambers.

GENUS PLECTOFRONDICULARIA LIEBUS, 1902

PLECTOFRONDICULARIA SP.

Plate 40, figure 4

Test elongate, much compressed, gradually tapering; edges sharply rounded; initial end bluntly rounded; early portion consisting of about six pairs of chambers, later chambers equitant, narrow, closely appressed; sutures not depressed; wall thicker in the early portion of the test, finely costate longitudinally, about twelve costae on a side; aperture not seen. Length of an incomplete specimen, 0.4 mm; width, 0.2 mm. Rare.

This form strongly resembles *Frondicularia striata* d'Orbigny, but the early portion is distinctly biserial.

FAMILY BULIMINIDAE JONES, 1876

GENUS TURRILLINA ANDREAE, 1884

TURRILLINA TROCHOIDES (REUSS)

Plate 40, figurs 5

Globigerina trochoides Reuss, *1845-1846*, Verst. Böhm. Kreide, p. 36, pl. 12, fig. 22; *1850 (1851)*, Haidinger's Naturw., vol. 4, p. 37, pl. 3, fig. 5. (Cretaceous).

Turrillina trochoides White, *1929*, Jour. Pal., vol. 3, no. 1, p. 46, pl. 5, fig. 4. (Cretaceous).

Test ovate in apertural view, triangular in side view, rapidly expanding from the initial end, many specimens being broader than long; chambers inflated except in the initial portion, rapidly enlarging; sutures distinct, depressed; surface smooth, aperture a slit without definite lip, on the inner margin of the last formed chamber. Length, 0.3–0.37 mm. Common.

The Tabasco specimens seems to be identical in every respect with the European. This species has been reported from the Upper Cretaceous of Lemberg, Poland, by Reuss, from the Upper Cretaceous Velasco shale by White, and from the Eocene of Kärnten, Austria, by Liebus.

GENUS BULIMINA D'ORBIGNY, 1826

BULIMINA CALLAHANI GALLOWAY AND MORREY, N. SP.

Plate 40, figure 6

Test robust, ovate; apical end with an angle of about 90°; apertural end rounded; chambers six to eight, very little inflated, rapidly increasing in size as added; sutures very little depressed, not limbate; surface of apical end ornamented with numerous, small costae which disappear in the last two or three chambers, and which curve and join others; between the costae are small ridges, giving a reticulate or coarsely punctate appearance; the apertural end is smooth excepting for medium-sized punctae; aperture a broad and short virguline opening, rarely with short tooth. Length, 0.31 mm.; breadth, 0.24 mm.

This species is differentiated from all other described species of the genus by its ornamentation. It resembles *B. velascoensis* (Cushman) but the early portion is conical rather than pyramidal, the striae are stronger, reach higher but are less regular, and in having the cross bars between the striae.

BULIMINA DECLIVIS Reuss

Plate 40, figures 8, 9

Bulimina declivis Reuss, *1863 1864)*, Sitz. k. Akad. Wiss. Wiem., vol. 48, p. 55, pl. 6, fig. 70; pl. 7, fig. 71. (Middle Oligocene).—Brady, *1884*, Rep. Voy. *Challenger*, Zool., vol. 9, p. 404, pl. 50, fig. 19 a-b. (Recent).

Test elongate, conical, tending to be three-sided, tapering to a blunt point at the apical end, some specimens with curved axis; chambers about ten, rapidly increasing in size as added, not inflated; sutures distinct, very slightly depressed with one or more reëntrants on the lower outside of most of the chambers; wall thick, very finely perforate; surface smooth, except for granulation on the apical end; aperture a large virguline opening in the septal face, near the middle of the oral end of the test, and nearly transverse to the axis of the test. Length, 0.2–0.45 mm; breadth, 0.14–0.3 mm. Abundant.

BULIMINA INFLATA Seguenza

Plate 40, figure 7

Bulimina inflata Seguenza, *1862*, Atti Accad. Gioenia Sci. Nat., ser. 2, vol. 18, p. 109, pl. 1, fig. 10 .(Pleistocene).

Test minute, highly inflated, nearly as broad as long, apical end pointed; whorls two to three; chambers increasing rapidly as added, regularly three to a whorl; sutures moderately deep; lower edges of chambers provided with short spines which pass upward into short costae; upper portion of chambers smooth; wall finely but conspicuously perforate; aperture a virguline opening extending up into the apertural face, nearly terminal, apparently without tooth. Length, about 0.25 mm; breadth, about 0.2 mm. Common.

The Tabasco specimens are smaller, more inflated and have less conspicuous spines than typical examples of the species which occur in many places and horizons throughout the world. If the specimens are young ones there are no adults occurring with them. They may be a new variety.

BULIMINA LAEVIGATA d'Orbigny

Plate 40, figure 10

Bulimina laevigata d'Orbigny, *1826*, Ann. Sci. Nat., vol. 7, p. 270, no. 12.—Fornasini, *1901*, Bull. Soc. Geol. Ital., vol. 20, p. 182, text fig. 4. (Pliocene).
Bulimina ovata Sidebottom, *1918*, Jour. Roy. Micr. Soc., p. 122, pl. 3, figs. 1-3. (Recent).
Bulimina pyrula Bagg., *1912*, U. S. Geol. Surv. Bull. 513, p. 39, pl. 9, fig. 1.

Test ovoid, apical end pointed; chambers numerous, three in the last whorl, the last one over two-thirds the length of the test; sutures

very little depressed; wall smooth, translucent in some specimens, very finely perforate; aperture an elongate slit at the end of the last chamber, with vertical tooth in some specimens. Length, 0.34–0.7 mm. Common.

This species differs from *B. affinis* d'Orbigny in having the later chambers longer.

BULIMINA TABASCOENSIS GALLOWAY AND MORREY, N. SP.
Plate 40, figure 11

Test robust, pyriform, apical end bluntly pointed, apertural end inflated; chambers six to eight, slightly inflated, rapidly increasing in size as added; wall thick, coarsely perforate; surface of apical end covered with about sixteen short, obscure costae which fade out in the last third of the test; aperture a broad comma-shaped opening on the inner face of the last chamber. Length, 0.2–0.35 mm; breadth, 0.14–0.28 mm. Common.

This species differs from *B. buchiana* (d'Orbigny) in having a wider angle at the apical end, less regular costae, and more rounded apical end. It differs from *B. velascoensis* (Cushman) in not being triangular, the sutures are distinct, and the costae are coarser. It differs from *B. callahani* n. sp. in the finer but more regular costae, making the surface sculpture much less ornate. It might be considered as a variety of *B. callahani.*

GENUS GLOBOBULIMINA CUSHMAN, 1927

GLOBOBULIMINA SOBRINA GALLOWAY AND MORREY, N. SP.
Plate 40, figure 12

Test robust, ovate, broadest near the base, oval in cross section; apical end broadly rounded; chambers embracing, only three visible; sutures distinct, slightly depressed; wall smooth, very finely perforate; aperture virguline, with vertical tooth, near the periphery. Length, 0.45 mm. Rare.

The Tabasco specimens are megaspheric and have a more rounded initial end than *B. pyrula* (d'Orbigny), the apertural end is less pointed, and it is not subtriangular in cross section. The form is shorter than *G. pacifica* Cushman.

Genus VIRGULINA d'Orbigny, 1826

VIRGULINA MUSTONI Andreae

Plate 40, figure 13

Virgulina mustoni Andreae, *1884*, Abh. geol. Specialkarte Elsass.-Loth., vol. 2, pt. 3, p. 254, pl. 11, fig. 4. (Middle Oligocene).

Test small, elongate, slightly tapering, appearing twisted; apical end subacute; chambers somewhat inflated, increasing in height as added, three to a whorl in the early part; gradually decreasing to two to a whorl at the apical end; sutures distinct, depressed, of clear shell material; surface smooth except for obscure striations on the initial end; wall conspicuously perforate; aperture comma-shaped, nearly terminal. Length, 0.3 mm. Rare.

Family UVIGERINIDAE Galloway and Wissler, 1927

Genus SIPHOGENERINA Schlumberger, 1883

SIPHOGENERINA DIGITALIS Galloway and Morrey, n. sp.

Plate 40, figure 14

Siphogenerina striata var. *curta* Cushman, part, *1926*, Proc. Nat. Mus., vol. 67, art. 25, p. 8, pl. 5, figs. 5-6, not pl. 2, fig. 5. (Recent).

Test small, elongate, nearly straight, early portion biserial, bulbous, flattened; uniserial portion cylindrical, of smaller diameter than the biserial part; chambers six in the biserial portion, later portion consisting of gradually enlarging cylindrical chambers; sutures slightly depressed, of clear shell material; surface ornamented by eight, sharp, longitudinal costae; apertural end broken. Length, 0.44 mm. Rare.

This species differs from *Uvigerina (Sagrina) raphanus* Parker and Jones, in the flattened early portion and in having fewer costae.

Genus SIPHONODOSARIA Silvestri, 1924

SIPHONODOSARIA ABYSSORUM (Brady)

Plate 40, figures 15, 16

Nodosaria abyssorum Brady, *1881*, Quart. Jour. Micr. Sci., n.s., vol. 21, p. 63; *1884*, Rep. Voy. *Challenger* Zool., vol. 9, p. 504, pl. 63, figs. 8-9. (Recent). —Nuttall, *1928*, Quart. Jour. Geol. Soc., vol. 84, p. 81, pl. 5, fig. 2. (Eocene-Oligocene-Miocene).

Siphonodosaria abyssorum Cushman, *1928*, Foraminifera, p. 257, pl. 36, figs. 23-24; pl. 37, fig. 20. (Tertiary and Recent).

Test elongate, nearly straight, initial end bulbous, with several short spines; chambers globular, irregular in size; sutures much con-

stricted except between the first two chambers; surface smooth; aperture round, large. Length, 0.4–0.5 mm. Rare.

Our specimens are all broken.

Family PLEUROSTOMELLIDAE Reuss, 1860

Genus ELLIPSOPOLYMORPHINA Silvestri, 1901

ELLIPSOPOLYMORPHINA SCHLICHTI (Silvestri)

Plate 40, figure 17

Ellipsopleurostomella schlichti Silvestri, *1903-1904,* Accad. Reale Sci., Torino, p. 4, text figs. 1-2. (Miocene).

Ellipsopleurostomella curta Cushman, *1928,* Contr. Cushman Lab. Foram. Res., vol. 4, pt. 4, p. 102, pl. 4, figs. 18-19 (not Cushman 1926.) (Cretaceous).

Test short, fusiform; chambers four, the last-formed one constituting two-thirds of the test; sutures flush, distinct; surface smooth; aperture nearly terminal, crescentic. Length, 0.3 mm. Rare.

METHODS AND TECHNIQUE

THE USE OF SELECTIVE STAINS IN PALEONTOLOGY[1]

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INTRODUCTION

In developing a technique of staining minute organic structures, biologists have gone far beyond paleontologists and have reaped rewards from their progress that should stimulate more effort along similar lines among the students of fossil organisms. The use of stains has had a very important part in the advancement of the biologic sciences. Staining methods have been used in biology only some eighty years, but so much dependence is placed upon them now that their application is an indispensable part of microtomy.

It is the main purpose of this paper to call the attention of paleontologists to the admirable results obtained by biologists from staining; to show some of the possibilities of staining for paleontology; and to present some methods that already have proved useful.

PURPOSE AND EFFECTS OF STAINING

Most biologic stains in common use have the property of staining one kind of tissue more than another. This differential staining action may be described figuratively by the term *selective*. Selectivity is the effect of differences in the chemical or physical affinity of the dye for the various tissues or substances in the object. The degree of selectivity in many stains is surprisingly great. Adjacent tissues apparently much alike in every way may have such greatly different affinity for a specific stain that one tissue will stain deeply and the other not at all. In this property of stains lies their virtue.

Selective staining is effective in many cases even where a microscopic examination discovers no differences between one tissue and another. Accordingly, selective stains may be more sensitive as indicators of structure and composition than the optical phenomena obtained by the various types of illumination commonly applied in biological microscopy.

The purpose of selective staining methods in biology and paleontology is to develop color contrasts between structures that are hard or impossible to distinguish without treatment. Since paleontologists are resorting more and more to the microscope for more discriminating studies, they are experiencing a need for indicators of obscure structures much in the same way as biologists did in the early stage of microtomy.

[1] Presented before the Paleontological Society, December 26, 1929. The writer is indebted to Prof. C. O. Dunbar, Yale University, for reading the manuscript, and to Dr. J. A. Cushman, United States Geological Survey, for furnishing specimens of foraminifera for experiments with staining not yet completed.

The mention of a few well-known problems in geology and paleontology is sufficient to make the advantages of a good staining technique evident to all. A notable example is the difficult problem of shell composition which affects so fundamentally the phylogenetic groupings and relationships of the families in foraminifera. Petrographers have similar difficulties in the microscopic analysis of very fine-grained sedimentary and metamorphic rocks. The study of the character and origin of soil profiles is made difficult by the ultra-microscopic texture of some of the essential constituents of the different soil zones. To solve these and numerous similar problems, the development of a good technique of selective staining in many instances would offer the most convenient and inexpensive if not the only practical solution.

SOME DIFFICULTIES IN THE DEVELOPMENT OF SELECTIVE STAINING TECHNIQUE

The development of selective staining technique in paleontology is a relatively new field of endeavor and is faced by a number of discouraging complications. One of the greatest difficulties encountered by invertebrate paleontologists is the instability of calcite and allied compounds in the presence of a great many of the conditioning, staining, and fixing solutions employed in biologic and textile dyeing. This condition prohibits the use on limestone of some very sensitive and valuable staining mixtures which are eminently successful on soft tissue. Also some of the dyes themselves are too active chemically in the presence of limestone to be applicable. A large number if not the majority of methods and formulas useful on textiles and soft tissue are either entirely inapplicable or require modification.

Some stains after fixation are soluble in the presence of mounting cements and liquids used in studying the objects stained. Malachite green, for instance, is not soluble in hot or cold water after it has been fixed by the boiling process described below, but is soluble in canada balsam dissolved by xylene; so, until a way was found to render it insoluble in the balsam solution, the usefulness of malachite green was greatly limited. It is unnecessary to argue that the permanence and fixity of dyes to fill ordinary laboratory requirements are essential considerations in developing staining formulae.[2]

One of the most discouraging difficulties to be overcome is the scattered state of the information which might be used in applying selective

[2] It is important that fixed dyes be insoluble in water because one of the most convenient ways of examining the surface of rock specimens to discover microscopic fossils is to immerse them in a pan of water, using a pan of such shape and size as to fit the microscope. Square or rectangular pans are preferable to round ones because of water wave phenomena. By filling surface irregularities, water eliminates most of the numerous optical interferences produced by rough and fractured surfaces. In fact a large share of the advantages obtained by a finely polished surface are obtainable for temporary purposes by the water immersion method. Except for certain exact requirements, water is preferable to oils because all traces of water are easy to remove.

stains to fossils. Those of us who are amateurs at staining and who are interested in stains only in a utilitarian way can thoroughly appreciate how hard it is to get practical information for our special purposes. No doubt many students and others have been turned from experimenting with stains because of the great difficulty involved in obtaining information; therefore, the person who selects the pertinent information now existing here and there and organizes it into one work generally available will probably do more to improve the technique of selective staining than one who discovers some new methods. A good compendium would prevent the discouragement which usually attends an ineffectual or difficult search through literature for help.

The permanence of stains is a consideration that should not be ignored in investigating new methods. Some of the synthetic dyes gradually lose their color properties in light, especially strong sunlight.

GENERAL NATURE OF STAINS AND THEIR APPLICATION

Selective stains may be classified in a number of ways, but for our present purposes it is sufficient to make two classes: those which stain without observable chemical reaction and those which react chemically with the material being dyed. In the first group are many of the natural dyes or extracts from organisms such as logwood extract (Haematoxylin), royal purple of classic fame, indigo, and many of the synthetic or coal tar products. These dyes apparently undergo no chemical reaction in staining and retain their original color properties, but assume the new physical property of fixity; that is, they are insoluble or permanently adherent. On the other hand, those dyes that stain by virtue of a chemical reaction usually develop colors not possessed by any of the constituents alone. Such dyes are picric acid and Heeger's formula. In a good many instances, the processes of selective staining used in biology are adaptations of *indicators* used in chemistry laboratories.

In a general way, the synthetic dyes are either applied directly or are applied after treating the subject with a mordant or some other conditioning agent according to the special requirements of each dye. The kind of mordant used depends upon the basic or acid character of the dye. If the dye is acid, a basic mordant is used and vice versa. Common mordants are aluminum hydroxide, aluminum alum, and tannic acid.

The impregnation of an object with aluminum hydroxide requires a special process because $Al(Oh)_3$ is insoluble in water. A method employed to avoid that difficulty is to use a solution of aluminum acetate for impregnation and then complete the hydrolysis of the acetate by steaming which leaves aluminum hydroxide diffused in the object or lying in its pores. $Al(OH)_3$ has affinity for several synthetic dyes.

The process just described has been employed extensively in textile dying and is mentioned here because it may be useful in staining certain kinds of rocks and fossil specimens. A solution of aluminum acetate is probably too active chemically for use as a mordant in limestone and cal-

careous fossils. Moreover, two other difficulties hinder its usefulness. One is that the use of any conditioning process for staining requires time. A second difficulty is that the steaming process for hydrolysis is likely to disrupt completed thin sections, unless the latter difficulty is avoided by completing the staining process as soon as the first surface of the thin section has been prepared. By this means the specimen could resist the mechanically disrupting effects of steaming.

Where mordants are necessary, it is best to form them as far as possible out of substances indigenous to the object. By forming a mordant *in situ* out of the indigenous elements, the mordant will represent accurately the original structure. One method of doing this on calcareous fossils is to calcine a very minute layer of the object. This requires a few brief applications of a very hot flame and cooling in water after each application. Other methods obtain a mordanting surface by the use of strong acid gases, acid solutions, or strong alkaline solutions. The latter type of treatment may serve either or both of the purposes of denuding stainable substances in the object or of altering one or more of the constituents into a mordanting substance. A clean surface is a prerequisite to successful staining.

SPECIAL STAINING METHODS

Malachite Green (C.I. No. 657)

Synonyms: *Emerald green, New victoria green, Diamond green, Solid green, Light green N.*

Weakly basic; solubility in water at 26°C, 7.6 per cent; in alcohol, 7.52 per cent.

Malachite green is a valuable stain for a number of purposes. It is sensitive in its selectivity and is easy to apply. For ordinary purposes it is applied in a water solution directly and requires no mordanting nor conditioning of the object. Limestones of unusually high purity will stain poorly or not at all.

Malachite green may be used to great advantage in staining pieces of limestone that are to be examined with a microscope to determine the texture or to find microscopic fossils. The stain is highly selective and ordinarily will cause each constituent particle to appear sharply defined even though the texture of the groundmass may have been obscure before staining. Accordingly, malachite green is a very great aid in examining specimens for minute fossils. It works less well on weathered surfaces than on broken or abraded and polished surfaces, because weathered surfaces of calcareous fossils are usually covered with at least an imperceptible, thin film of argillaceous material that was either precipitated out of ground water by the more soluble calcite of the specimen, or originated as a residue of indigenous clay. Inasmuch as malachite green has very great affinity for clay (kaolin) and possibly also for certain forms of hydrous iron oxide, fossils coated with even an imperceptibly thin layer of clay will stain heavily. This difficulty, however, might possibly be avoided in

some cases by cleansing the weathered surface in a hot solution of potassium hydroxide.

Application of malachite green.—The method of application is quite simple. It is best to have at hand a stock solution of the dye composed as follows: malachite green and water in the proportion by weight of 1 to 99 or 1.5 to 98.5. The solution will appear quite dense. By adding 5 to 10 weights of pure grain alcohol the keeping qualities of the solution are improved.

1. Prepare staining bath by adding 1 to 2 measures of stock solution to 200 measures of water. The volume of the bath should exceed that of the specimens by 10 to 20 or more times. (The proper strength of the staining bath is best determined by each person for his own special needs. A few trials will enable one to make the necessary adjustments.)

2. Immerse the specimens.

3. Boil until the solution clears. The dye becomes fixed and is insoluble in water.

4. Rinse specimens. Occasionally it is necessary to clean a scum from the face of the specimen with a stiff brush and water. A small amount of grain alcohol seems to reduce the chances of scum deposits, but too much alcohol inhibits fixation.

The specimens are then ready for examination. Since depth of staining depends mainly upon texture and porosity of the object, the rate of diffusion of the dye solution, and the temperature, it is evident that in the above method, only the surface of relatively impervious specimens will be dyed, which is sufficient for most purposes. Deeper and more highly selective staining will be obtained by lengthening the period of immersion in the bath to hours or days according to the results desired and by increasing the rate of diffusion with alcohol.

If it is desired to mount the stained specimens with canada balsam, operation No. 4 above should be supplanted by the following operations:

4. Dry the specimens. By removing them from the boiling-hot water they will dry quickly.

5. Immerse in hot xylene for a few minutes. These last operations may be better delayed until the specimens are ready to mount. The xylene remaining in the pores of the object will help to avoid the difficulty of getting air bubbles between the object and the slide or coverslip.

Staining of thin-sections.—To stain thin-sections, two different methods may be used. If it is desired to stain a finished thin-section, the following method is recommended:

1. Clean surface of section with soft cloth, coverglass being removed.

2. Immerse and let remain for several hours in staining bath prepared as above, but about twice as strong. Probably it would be best not to add more alcohol than the stock solution already contains. Deeper penetration and better staining will be obtained by using a bath composed of about 3 measures of the

stock solution to 97 of water and soaking the specimen two or three days, keeping the bath covered to prevent evaporation and the formation of a scum.

3. Remove and wipe the surface clean with soft cloth, being careful not to tear off any part of the section. Care is necessary because continued soaking in water may loosen part of the section from the cement. If the cloth is moistened with alcohol the cleansing operation is easier provided the alcohol does not disrupt the specimen.

4. Dry.

5. Immerse several seconds to a minute or more in warm xylene. Remove slide from the xylene and just before the last xylene has evaporated from the object cover the object with a drop of liquid canada balsam being careful to avoid an excessive amount, for an excess frequently leads to any of several difficulties.

6. Lay on the coverslip and let it sink into position by its own weight with little or no pressing.

7. The canada balsam may then be dried slowly to the proper hardness by placing the slide over a radiator or in an oven heated by electric lights, or any arrangement to secure a slow drying.

If a more complete fixation of the dye be desired, the section may be steamed by supporting the slide (lying flat with the object side upward) above water in an enclosed vessel and boiling the water for a few minutes. This procedure is dangerous because of the chances of disrupting the delicate section.

The second method, which is better, is to stain the sections after the first face has been prepared. The objects can be treated as described above in the method for staining chips. It is better to soak the specimens as long as time will permit. If it is necessary to complete the specimens hurriedly, the process of impregnation can be expedited greatly by doubling the strength of the staining bath and heating it to a temperature of 75°-85°C. and letting it remain thus for about an hour. Before fixation by boiling the staining bath should be diluted to normal strength by the addition of an equal quantity of water.

It is important to know that in order to be effective the stain for thin-sections must be much more intense than for polished sections.

Additional uses of malachite green are based upon its great affinity for clay or kaolin. It may be used as an indicator for the presence of kaolin in weathered crystalline rocks or in limestones. Holmes recommends the use of xylene as a malachite green solvent in staining friable specimens such as weathered igneous rocks because water tends to disrupt kaolin bodies. I tried his suggestion, but found malachite green is insoluble in xylene. It possibly should not be assumed that Holmes was in error, because synthetic dyes on the market have varied greatly in composition, properties, and even in the names given to them until recently when the commission on biologic stains erected standards of purity and names. However, malachite green is soluble in xylene mixed with a small amount of canada balsam. Possibly other resinous substances would aid solution even better.

Malachite green has considerable possibilities as a stain to differentiate the test structures in the adventitious tests of Recent or older foraminifera. In staining Pennsylvania limestones, it was found that shells of *Tetrataxis, Polytaxis,* and textularians would stain whereas those of fusulinids would not. This is suggestive of possibilities.

The dye can be removed from vessels and other objects by diluted strong acids.

Alizarine (C.I. No. 1027)

Acid dye; solubility at 26°C., in water none, in alcohol 0.125 per cent.

Alizarine, alizarine red S (C.I. No. 1034), and pupurin (C.I. No. 1037) are members of the oxyquinone group of dyes. "They have the property of combining with metallic oxides to form so-called 'lakes,' insoluble compounds of different color from the dye entering into them. This makes them valuable ones to use after the mordanting with aluminum iron, or chromium compounds."[3]

With alizarine, salts of aluminum and tin produce various shades of red; ferric oxide produces dark violet; chromium oxide produces a claret color; and calcium produces blue. Pupurin has similar reactions except that with alumina scarlet lakes are formed. This group of dyes has considerable possibilities, it seems to me. The lack of supplies prevented me from trying pupurin and alizarine red S., but they are mentioned here because the greater solubility of alizarine red S.,[4] and possibly also pupurin, makes them more convenient to use than alizarine.

A special use for alizarine was found which has considerable value. It is very good for staining weathered surfaces of limestone and fossils in the solution to be described below.

Method of alizarine staining.—The following formula for staining with alizarine is presented in preliminary form. Better proportions may be devised by other workers in stains.

1. Mix 1 measure concentrated solution of KOH in H_2O with 119 measures of water.
2. Dissolve maximum amount of alizarine at room temperature.
3. Immerse specimen for a few hours. The staining may possibly be accelerated by warming the solution, but in most cases boiling destroys the lakes formed.
4. Remove and wash very carefully in a slow current of water until KOH is extracted from specimen.
5. Specimen is ready for observation or mounting.

This formula was tried on washed sediments containing foraminifera. It made the fossils somewhat more conspicuous by developing color con-

[3] Conn, H. J. Biological Stains. A handbook on the nature and uses of the dyes employed in the biological laboratory. Geneva, N.Y.

[4] II Alizarine red S. at 26°C. has a solubility of 7.69 per cent in water; and in alcohol 0.15 per cent. Is an acid dye. I did not find definite information about the solubility of pupurin.

trasts in surficial or exterior structures of the shell. For instance, specimens of *Bradyina* showed bolder relief and the linear pits were filled with grayish blue lake making them notably distinct. Specimens of *Fusulina* from the Lonsdale limestone of Illinois exhibited lakes over the antethecal pores. Antethecal pores had not been observed on the outer surface of this species until staining was tried.

It is probably advisable to stain only a portion of the fossiliferous sediment, because many specimens are discolored so unevenly by the stain that photography would be difficult unless certain ray filters were employed. For study it is frequently worth while to have both stained and unstained specimens side by side.

A special advantage of this stain formula lies in the cleansing property of KOH which tends to denude the specimens of extraneous clay, thus exposing a surface more representative of the specimen. Accordingly, weathered surfaces can be stained successfully.

HEEGER'S METHOD[5]

Heeger's method is one of the well-known means of differentiating between calcite and dolomite. It is convenient and valuable for dyeing fossils in limestone.

Formula for Quick Staining

1. Compose the staining bath[6] as follows:

Add 2 measures of concentrated hydrochloric acid to 88 measures of water and then add 10 measures of concentrated potassium ferricyanide solution.

2. Immerse the specimen for 30 to 70 seconds.

3. Wash specimen in still or very gentle current of water taking care not to remove the delicate lake of turnbull blue on parts of the surface.

4. The specimen may then be observed under water or dry, but canada balsam disrupts the lake. A method of mounting to avoid this difficulty has not been devised by me.

Better effects may be gained by using a more dilute solution of hydrochloric acid and leaving the specimen in the staining bath for a longer time. The length of time necessary to get the desired effects can be learned after a very few trials. The staining reaction is made possible, according to Holmes, by the fact that most limestone or even calcite crystals contain enough iron to produce a lake of Turnbull's blue. A trace of iron is sufficient.

It is obvious that a weak solution of HCl is a prerequisite to good staining effects because a vigorous effervescence would prevent the deposition

[5] Heeger, W., Centralblatt f. Min., etc., p. 44, 1913.

[6] This staining solution is unstable and slowly emits cyanide fumes which are extremely poisonous to breathe, but the emission is too slow to do harm in well-ventilated rooms. Also considerable care should be used not to let any of the older solutions touch the skin to any considerable extent, for prussic acid and similar compounds are dangerous even to touch. With reasonable care no harm will result from the use of Heeger's solution.

of a properly distributed lake or if very vigorous would prevent the deposition of any lake at all.

Heeger's method is recommended for the development of strong contrast between calcareous fossils and their matrix and especially for delimiting shell structures. In studying sections of corals, bryozoans, foraminifers, brachiopods, and others, this stain has proved to be particularly valuable and convenient in delimiting shell structures for purposes of observation and photography. While making thin-sections of minute fusulinids, whose proloculum may be as small as 30 microns, I have made it a regular practice to keep at hand a fairly strong staining solution as a help in locating the proloculum, a task that frequently is hard. For this use, the solution is made more acidic and is applied with a medicine dropper. The time required for staining usually is no longer than 30 seconds. The etching produced by the acid has additional advantages.

Fairbanks' "Modification of Lemberg's Staining Formula"

Fairbanks[7] has described a modification of Lemberg's staining method that is useful in work with some fossils. He writes in part as follows:

> Lemburg's solution is commonly prepared by boiling the following constituents together for about 25 minutes:
>
> 6 parts logwood chips
> 4 parts aluminum chloride
> 60 parts water
>
> Several factors, such as time and concentration, enter into the differential staining properties of this solution. The concentration of the active principle of logwood cannot be controlled by using the above formula. A variable amount of haematoxylin and hematein, active principles of logwood, are obtained by boiling logwood chips. In fact certain varieties of logwood contain a very small amount of this material. This explains why uniform results have not been obtained in staining experiments using a solution of this nature.
>
> The writer has used the following modification of Lemberg's solution with excellent and uniform results:
>
> 0.24 grams haematoxylin
> 1.6 grams aluminum chloride
> 24 cc. water.
>
> This solution is brought to a boiling point and then cooled. A small amount of hydrogen peroxide is then added. . . . The . . . section is then immersed in the cold solution for about 5 minutes and then rinsed without danger of removing the stain.

The objects may be mounted as desired except that soft balsam should be used and very slowly dried. This method is a well known test for dif-

[7] Fairbanks, E. E., A Modification of Lemberg's Staining Method: Am. Mineralogist, x:126, 1925.
Lemberg, J., Zeits. d. deutsch Geol. Ges., XXXI, p. 489, 1887; XLIV, p. 231, 1890.

ferentiating calcite and dolomite, the calcite being stained deeply while dolomite is not stained at all.

Additional References

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Lee, A. B. The Microtomists Vade-mecum: Blakistons (An extensive handbook of biological laboratory technique).

Conn, H. J., Biological Stains: A handbook on the nature and uses of the dyes employed in the biological laboratory: Second Edition, 1929, Geneva, New York. (Besides the field covered as indicated in the title, this book has a large list of references—mostly biological treatises.)

PALEONTOLOGICAL NOTES

ADDITIONAL PLIOCENE AND PLEISTOCENE FOSSILS FROM LOWER CALIFORNIA

LEO GEORGE HERTLEIN

This paper contains records of species from the Pliocene or Pliestocene, mostly from the gulf side of Lower California, collected by geologists of the Marland Oil Company. The writer was permitted to make this study through the kindness of the late James Perrin Smith and the collections are deposited of Leland Stanford Junior University.

Most of the late Tertiary and Pleistocene species from the collections of the Marland Oil Company have been recorded, but there are some from localities which were not included in previous papers by Hertlein[1] and Hanna and Hertlein.[2] These papers should be consulted for citations to the literature.

A few species are included in the present paper which were reported under other names in previous lists.

The collections all appear to represent an upper Pliocene or Pleistocene age and most of the species are now found living in the Gulf of California.

Locality 44 (L. S. J. U.) Arroya Fortuna, north of San Jose del Cabo, Lower California; C. R. Swarts, collector.

Ostrea megadon Hanley.

Locality 45 (L. S. J. U.) Santa Rosalia, Lower California; C. H. Beal, collector.

Clypeaster deserti? Kew [Fragment].

Locality 46 (L. S. J. U.) Post-Eocene sandstone on north edge of Ballenas Bay Quadrangle, Lower California.

Chione cf. succincta Valenciennes.

Dosinia ponderosa Gray.

Macron aethiops Reeve.

Polinices reclusianus Deshayes.

Turritella gonostoma Valenciennes.

The Mollusks from this locality are not conclusive as to age and may be either Pliocene or Pleistocene. Taken as a whole the evidence suggests Pleistocene.

Locality 50 (L. S. J. U.) Rancho Refugio, north of San Jose del Cabo, Lower California; C. R. Swarts, collector.

Anomia peruviana d'Orbigny.

[1] Hertlein, L. G., Proc. Calif. Acad. Sci., ser. 4, vol. 14, no. 1, 1925, pp. 1-35.
[2] Hanna, G. D. und L. G. Hertlein, Proc. Calif. Acad. Sci., ser. 4, vol. 16, no. 6, 1927, pp. 140-143.

Locality 52 (L. S. J. U.) Cerro El Zacato, on coast north of Santiago, Lower California; C. R. Swarts, collector.

Anomia peruviana d'Orbigny.

Locality 55 (L. S. J. U.) Arroyo Asuncion, Scammon Lagoon Quadrangle, Lower California; B. F. Hake, collector. Salada, Pliocene.

Dendraster pentagonalis Israelsky.

Locality 61 (L. S. J. U.) Coronados Island, Gulf of California; T. J. Cullen, collector.

Arca sp.

Chione succincta Valenciennes.

Codakia distinguendo Tryon.

Pecten circularis Sowerby.

Locality 62 (L. S. J. U.), Float, five kilometers north of Santa Rosalia, Lower California; C. H. Beal, collector.

Ostrea heermanni Conrad.

Pecten circularis Sowerby. [Reported as "*Pecten cerrosensis mendenhalli* Arnold," in 1925].

Locality 63 (L. S. J. U.) Arroyo near La Palma, Lower California. Pebbly sandstone near Comondu-Salada contact.

Ostrea megodon Hanley.

Pecten circularis Sowerby.

Locality 69 (L. S. J. U.) Arroyo de las Virgines, 10 miles northwest of Santa Rosalia, Santa Rosalia Quadrangle, Lower California; B. F. Hake, collector.

Arca sp.

Pecten circularis Sowerby. [Listed as "*P. cerrosensis mendenhalli* Arnold," in 1925].

Turritella gonostoma Valenciennes.

Locality 75 (L. S. J. U.) near west line above San Juan Arroyo, Jesus Maria Quadrangle, Lower California; C. H. Beal, collector, 1921; Pliocene.

Macron aethiops Reeve.

Polinices sp.

Serpula sp.

Balanus tintinnabulum cf. B. t. *californicus Pilsbry.*

The original label refers this collection to the Pliocene. The molluscan evidence is not conclusive but suggests a Pleistocene age.

Locality 78 (L. S. J. U.) Arroyo Asuncion, Scammon Lagoon. Quadrangle, Lower California; B. F. Hake, collector.

Ostrea vespertina Conrad.

Locality 81 (L. S. J. U.) Arroyo Tarabilla, 2 kilometers from the Gulf coast, north of La Paz, Lower California; bottom green sandstone; C. R. Swarts, collector.

Ostrea chilensis Philippi.

Locality 83 (L. S. J. U.) District south of La Paz, Arroyo Santiago where the trail from Rancho Ensenal enters the arroyo opposite the town of Santiago, Lower California; C. R. Swarts, collector.

Ostrea megadon Hanley.

Ostrea mexicana Sowerby.

Locality 85 (L. S. J. U.) Arroyo Cadeje above the Rancho Cadeje, Lower California.

Ostrea heermanni Conrad.

CHANGES OF NOMENCLATURE OF SOME RECENT AND FOSSIL PECTINIDAE FROM JAPAN, PORTO RICO, SOUTH AMERICA, NEW ZEALAND, AND CALIFORNIA

LEO GEORGE HERTLEIN

During the course of work dealing with a study of recent and fossil Pectinidae it was noticed that several names were preoccupied. It seems best to rectify a few of these records since it leads to confusion in the literature, where the preoccupied names have long been used for well-known species.

PECTEN INTUSCOSTATUS VAR. SAWANENSIS HERTLEIN, new name

Pecten intuscostatus var. *multicostata* Yokoyama, *1926*, Jour. Fac. Sci. Imp. Univ. Tokyo, sec. 2, vol. 1, pt. 8, September 18, 1926, p. 305. "Upper and lower horizon Sawané. Musashinos." Japan; upper Pliocene or lower Pleistocene. Not *Pecten multicostatus* Nilsson, Petrefacta Suecana; 1827, p. 21 "in stratis ad Balsberg depositis". Sweden; Cretaceous. Not *Pecten multicostatus* Reeve, Conch. Icon. vol. 7, 1852, *Pecten*, Sp. 173, pl. 35, fig. 173. "New Zealand"; Recent. [=*Pecten zealandiae* Gray, according to Suter, Manual of New Zealand Mollusca, 1913, p. 878]. Not *Pecten tehuelchus* d'Orbigny var. *multicostata* Bavay, Jour. de Conchyl. vol. 54, 1906, p. 9, pl. 1, fig. 4. Argentina; Recent.

The specific name *multicostatus* is preoccupied in the genus *Pecten* by Nilsson and Reeve and *multicostata* has been used by Bavay. The variety described by Yokoyama can take the name *Pecten intuscostatus* var. *sawanensis*.

PECTEN PLEBEJUS YOKOYAMA

Pecten plebejus Yokoyama, *1926*, Jour. Fac. Sci. Imp. Univ. Tokyo, sec. 2, vol. 1, pt. 8, September 18, 1926, p. 305, pl. 36, figs. 1 and 2. "Kaidate (frequent). Upper and lower horizons, Sawané". Upper Pliocene or lower Pleistocene. Not *Pecten plebeius* Lamarck, Ann. du Mus. d'Hist. Nat. vol. 8, 1806, p. 353. "Grignon", Eocene.

Apparently Yokoyama's name *P. plebejus* is valid and not preoccupied but it is interesting to note that *Pecten plebeius* Lamarck[1] has been spelled

[1] Ann. du Mus. d'Hist. Nat. vol. 8, 1806, p. 353. "Grignon", Eocene; also Anim. S. vertèb. vol. 6, 1819, p. 183.

"plebejus" by Brocchi[2] and others. This is not the original spelling of Lamarck, which should be followed.

PECTEN (CHLAMYS) PORTORICOENSIS VAR. HUBBARDI HERTLEIN, new name

Pecten (Chlamys) portoricoensis var. *grandis* Hubbard, *1920,* New York Acad. Sci. Sci. Surv. Porto Rico and the Virgin Islands, vol. 3, pt. 2, p. 89, pl. 11, figs. 5 and 6. "Lares road at K. 32.9". "San Sebastian shale" and "K. 29.2 Lares road", Porto Rico; middle Oligocene. Not *Pecten grandis* Sowerby, Mineral conchology, vol. 6, 1828, p. 163. T. 585, "at Ramsholt in a native bed, and Newbourn, and in various other parts of the Suffolk Crag."

There already exists a *Pecten grandis* Sowerby; therefore *hubbardi* is suggested for the variety of *Pecten portoricoensis* described by Hubbard.

PECTEN OCTOPLICOIDES HERTLEIN, new name

Pecten octoplicatus Stanton, *1901,* Rept. Princeton Expedition to Patagonia, Palaeontology, vol. 4, pt. 1, p. 14, pl. 4, figs. 2 and 3, "abundant in the ammonite (Belgrano) beds at mouth of cañon four miles east of Lake Pueyrrydon," Patagonia; Cretaceous. Not *Pecten octoplicatus* Bittner, Abhandl. K. K. Geol. Reichsanstalt, bd. 18, heft 1, 1895, p. 162, pl. 19, fig. 19. St. Cassian, Austria; Triassic.

The name *Pecten octoplicatus* was first used by Bittner. *Pecten octoplicoides* is proposed for the Cretaceous species of South America later described by Stanton.

PECTEN TEHUELCHUS D'ORBIGNY VAR. PHANEUS HERTLEIN, new name

Pecten tehuelchus d'Orbigny var. *multicostata* Bavay, *1906,* Jour. de Conchyl. vol. 54, p. 9, pl. 1, fig. 4. Argentina; fossil. Not *Pecten multicostatus* Nilsson, Petrefacta Suecana, 1827, p. 21 "in stratis ad Balsberg depositis"; Sweden; Cretaceous. Not *Pecten multicostatus* Reeve, Conch. Icon. vol. 7, 1852, *Pecten,* Sp. 173, pl. 35, fig. 173. "New Zealand"; Recent. [=*Pecten zelandiae* Gray, according to Suter, Manual of New Zealand Mollusca, 1913, p. 878].

According to the rules of nomenclature *Pecten tehuelchus* var. *multicostata* Bavay is preoccupied by the name *Pecten multicostatus* which was earlier used by Nilsson and Reeve. The name *phaneus* is here proposed for the variety described by Bavay.

PECTEN TEHUELCHUS D'ORBIGNY VAR. SPINULOSOIDES, HERTLEIN, new name

Pecten tehuelchus d'Orbigny var. *spinulosa* Bavay, *1906,* Jour. de Conchyl. vol. 54, p. 9, pl. 1, fig. 5. Argentina; fossil. Not *Pecten spinulosus* Goldfuss, Petrefacta Germaniae bd. 2, 1834-1840, p. 61, pl. 95, fig. 3. "E regionibus Viennensibus".

Bavay's varietal name may be considered preoccupied by Goldfuss who used *Pecten spinulosus.* The name *spinulosoides* is proposed for the South American variety of *Pecten tehuelchus* d'Orbigny.

[2] Conch. Fossile Subapennina, vol. 2, 1814, p. 577.

PECTEN ZEELANDONUS HERTLEIN, new name

Pecten imparicostatus Bavay, *1905*, Jour. de Conchyl. vol. 53, p. 23, pl. 2, figs. 6 and 7. "Novae Zelandiae mare"; Recent. Not *Pecten imparicostatus* Bittner, Abhandl. K. K. Geol. Reichsanstalt, bd. 18, heft 1, 1895, p. 162, pl. 19, fig. 7. St. Cassian, Austria; Triassic.

Bavay's name is unavailable because of its previous use by Bittner; therefore *Pecten zeelandonus* is proposed.

PECTEN CRASSICARDO NOMLANDI HERTLEIN, new name

Pecten crassicardo biformatus Nomland, *1917*, Univ. Calif. Publ. Bull. Dept. Geol. vol. 10, no. 18, Nov. 8, p. 307, pl. 18, figs. 1, 1a, 1b; pl. 19, fig. 4. "near western boundary of Sec. 13, T. 32 S, R. 29 E, M. D. B. & M., Tejon Hills, Caliente Quadrangle, Kern County." "Santa Margarita" Miocene. Not *Pecten biformatus* Bittner, Palaeontologica Indica, ser. 15, Himalaya Fossils, vol. 3, pt. 2, 1899, p. 59, pl. 10, figs, 23 and 24. Himalaya, Norisch, Upper Triassic.

Nomland's use of the subspecific name *biformatus* is preceded by Bittner. The California subspecies may take the name *nomlandi*.

PECTEN HODGEI HERTLEIN

Pecten hodgei Hertlein, *1925*, Bull. South. Calif. Acad. Sci., vol. 24, pt. 2, p. 42, pl. 4, figs. 1 and 2. Miocene of Coalinga region, California. Not *Pecten hodgii* Hubbard, New York Acad. Sci. Sci. Survey Porto Rico and the Virgin Islands, vol. 3, pt. 2, 1920, p. 93, pl. 12, fig. 5. "Quebradillas limestone (rare)," Porto Rico.

Attention is here called to the similarity in spelling of the specific name *hodgii* and *hodgei*. The first was used by Mr. Hubbard in honor of Dr. E. T. Hodge, prior to the present writer's use of the designation *"hodgei"*. Although both species were named for Dr. Hodge, according to the rules of nomenclature it appears that the difference in spelling permits the use of both names.

PECTEN (PLAGIOCTENIUM) SEYMOURENSIS DALL AND OCHSNER

Pecten seymourensis Dall and Ochsner, *1928*, Proc. Calif. Acad. Sci. ser. 4, vol. 17, no. 4, June 22, 1928, p. 119, pl. 2, fig. 22. "upper horizon, Seymour Island, Galapagos Group. Probably Pliocene." Not *Chlamys seymouri* Marwick, Trans. N. Z. Inst. vol. 58, Feb. 28, 1928, p. 457, fig. 23. "Momoe-a-toa; (?) Whenuataru Peninsula."

It may be noted that *Pecten seymourensis* Dall and Ochsner is not preoccupied by *Chlamys seymouri* Marwick. Even if *Chlamys* is considered as a separate genus, this does not assist in simplifying the problem in nomenclature because the species described by Dall and Ochsner can be assigned to the section *Plagioctenium* which belongs with the *Chlamys* group. The names *seymouri* and *seymourensis*, however, are both apparently valid according to the usual application of the rules of nomenclature.

REVIEWS AND NEW PUBLICATIONS

LEE, J. S., CHEN, S., and CHU, S., Huanglung Limestone and its Fauna. Memoirs, National Research Institute of Geology, No. IX, p. 85-142, 1 table, plates II-XV, 1930.

The senior author is already well known for his important contributions on the Fusulinidae and Pennsylvanian Stratigraphy of China. The present short monograph contains valuable new information of particular interest to the students of fusulinids.

The Huanglung limestone of southeast China apparently is equivalent to the Penchi Series in north China and probably the Pottsville of North America. It is underlain by Viséan or older rocks and is overlain disconformably by the Chihsia limestone, whose age is uncertain except that it is Pennsylvanian or Permian. The Huanglung limestone has two faunal zones. The upper one is characterized by the presence of *Fusulina* and more advanced *Fusulinella* while the lower zone contains primitive *Fusulinella* and *Fusulina*. Moreover, *Fusiella* and *Schubertella* are very numerous in the lower and scarce in the upper zones.

The fauna described in this report contains thirty-one new and fifteen old species and varieties of foraminifera, of which nineteen new and seven old ones are fusulines; four new species of Tabulata; and one new tetracoral.

A new fusulinid genus *Fusiella* is introduced. It is minute, fusiform, planiseptate, and has thin walls probably covered with secondary deposition and apparently lacks diaphanotheca. The nucleoconch is a distinct stage having oblique orientation. The absence of diaphanotheca and the distinctly oblique arrangement of the nucleoconch in *Fusiella* seem to distinguish this genus from *Wedekindia* Dunbar and Henbest. Both of these genera were described the same month in 1930.

The discovery of *Fusiella* is interesting in that it furnishes additional support for the validity of the genus *Schubertella* and gives new information about the geological range of such peculiar forms. Its discovery vindicates in a measure the view of Staff and Wedekind relative to their use of degree of symmetry in the early stage as a major criterion for generic distinctions. It still remains impossible, however, to use this character in the same way that they have done.

The enigma of *Schubertella* again appears. After studying many specimens, Lee, Chen and Chu have come to the conclusion that this is a valid genus, and decide that these small individuals are not immature specimens of other genera.

Students of fusulinids have been very much puzzled by the reported association of *Fusulinella* (Moscovian or Pottsville age) with *Doliolina* and *Neoschwagerina* (Permian age) at different places in Eurasia. This situation appears so anomalous and so much unlike that in North America, that the validity of those reports has been doubted. Lee, Chen, and Chu discuss this enigma briefly (p. 129) and come to the following conclusion: "In a large number of specimens of fusulinids we have never found a

single Moscovian form extending as high as Permian; and in the numerous microslides which contain *Doliolina* and *Neoschwagerina,* we have never observed any trace of *Neofusulinella* [*Fusulinella*]. We therefore entertain a strong suspicion that the alleged association of *Neofusulinella phairayensis* may not be due to mislabeling." We wonder if the presence of "not" in the last sentence was unintentional? It will be most fortunate, indeed, if the authors can investigate this problem still further.

In spite of the fact that this small monograph contains very valuable information, there are a number of features in it that belittle its importance to an unfortunately great degree. Those who need to study the descriptions carefully will wish that the authors had included measurements of more specimens in order that a better idea of the range of variation in a species might be obtained. Out of 140 figures of Fusulinidae, 19 are so obscure that they are useless, and 65 of the specimens illustrated were sectioned in such orientation or position that they give little or no information about the essential characteristics of the species. And worse still some species are illustrated only by inadequate sections. In making these criticisms, the reviewer intends to give liberal credit for sections that for special reasons are best left excentric or obliquely oriented. The illustrations of the specimens representing the new genus *Fusiella* leave much to be supposed. Without doubt, a number of the sections were very difficult to make. It is no small task to make good sections of the primitive and more minute fusulinids.

Another matter of debatable wisdom is the identification or description and naming of the smaller foraminifers by means only of thin sections. To be sure it is quite probable that in the future students of Foraminifera will resort more and more to sectioning for discriminating studies, but in this period of transition workers will experience vexing difficulty unless the exterior as well as the internal features are illustrated.

The nomenclatorial usage of Lee, Chen, and Chu relative to certain genera brings up a number of questions of special and general interest to taxonomists. The genera in question are *Fusulina, Fusulinella, Girtyina,* and *Neofusulinella.* The hectic history of the first three genera is reviewed at length by Dunbar and Condra, "The Fusulinidae of the Pennsylvanian System in Nebraska," and by Dunbar and Henbest, in the American Journal of Science, November, 1930; and is too detailed for repetition here. Suffice it to say that the generic name *Girtyina* Staff and Wedekind is either a synonym of *Triticites* Girty or *Fusulina* Fischer de Waldheim according to one's interpretation of Article 30 I(a), International Rules of Zoological Nomenclature. See also Opinion 65, *opus citatum.* The generic name *Neofusulinella* was introduced by Deprat for fusiform fusulinellids under the mistaken notion that Möller's type of *Fusulinella* has a short axis; but, as a matter of fact, the genotype of *Fusulinella* is fusiform; therefore, the name *Neofusulinella* must be rejected as a synonym. Lee, Chen, and Chu recognize these things, but in seeking to rectify the situation have added to the confusion by arbitrarily retaining *Girtyina* as the typical subgenus of *Fusulina* and *Neofusulinella* as the

typical subgenus of *Fusulinella,* but this procedure is irregular (see articles 9 and 25, op. cit.) In reference to their retention of *Girtyina,* Lee, Chen, and Chu (p. 131) say that "This procedure, the writers admit, does not altogether satisfy the International Rules of Zoological Nomenclature, but is adopted as an expediency to comply with the accomplished facts. A rigid adherence to the Rules would necessitate a drastic and confusing change of a mass of names, which the writers are not inclined to undertake at present." The reviewer and many others sympathize entirely with their reluctance to complicate the names of this complex group by correcting errors, but in order to save future and present confusion and possibly needless contention, it is good practice to correct errors as soon as they are discovered. Not many feel that it is just to perpetuate erroneous and in some cases irresponsible or haphazard introductions of new names. Needless to say, the Rules may work hardships, but most scholars are willing to suffer the limitations they impose in return for the many more numerous advantages they hold for the profession. Moreover, the committee on rules is qualified to pass judgment on special cases and though slow-working at times has proved to be eminently efficacious.

It is hoped that these criticisms do not overshadow the better parts of the work.

LLOYD G. HENBEST

E. JAWORSKI, Bibliographia Palaeontologica für die Jahre 1914-1926. Allgemeine Paläontologie. Spezielle Paläozoologie: Protozoa, Coelenterata, Echinodermata, Molluscoidea, Mollusca (ausser cephalopoda). Leipzig: Max Weg. Price 18 Marks.

The work of Dr. Jaworski has 223 pages devoted to the literature of Paleontology published during the years 1914 to 1926. The main headings are given in the above title. Under each of these main groupings are subordinate subjects under which papers are classified. For example, under the first main heading of General Paleontology are fourteen subdivisions including such subjects as Bibliography, Fossilization, Systematic and Nomenclatorial Papers, Correlation and Chronology, Paleontology, Paleogeography and Paleophytogeography, Paleoclimatology, Phylogeny, Preparation and Methods, Collections and Catalogues, Regional Paleontology, History of Paleontology, etc. Papers under the different groups of the animal and plant kingdoms are again subdivided by geologic periods so that it becomes possible to find all the papers under Paleozoic Foraminifera, for example, on pages 55-57. This work will be invaluable to the worker in Paleontology, and it is to be hoped that it will have a supplement which will bring it up to the next five year period as soon as it can be conveniently done.

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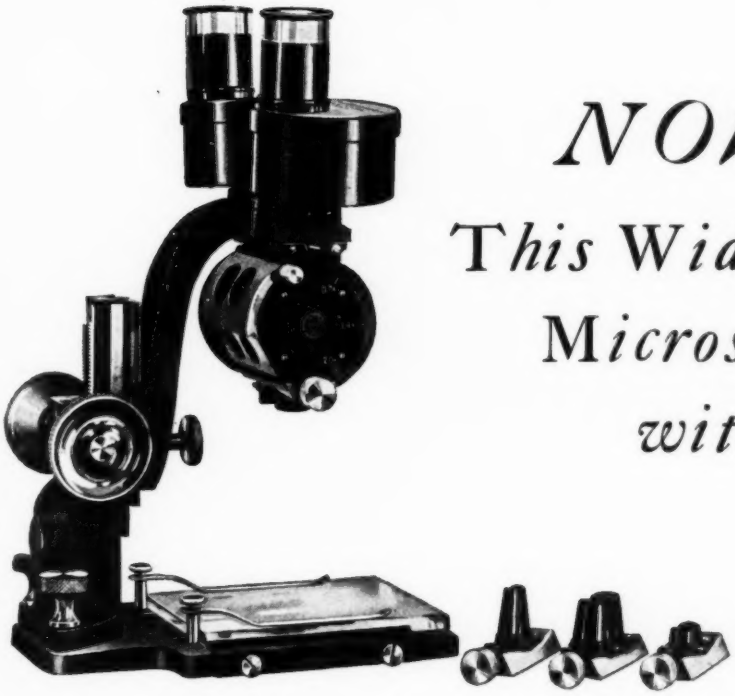

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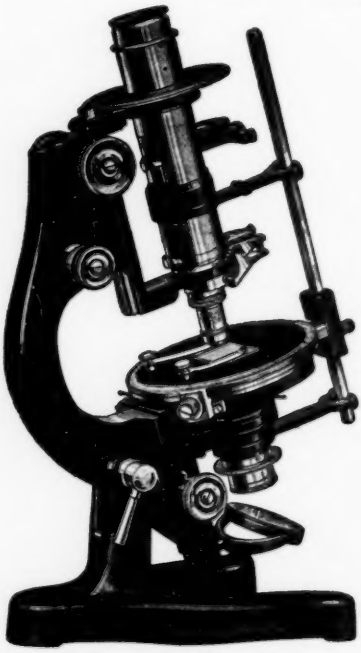

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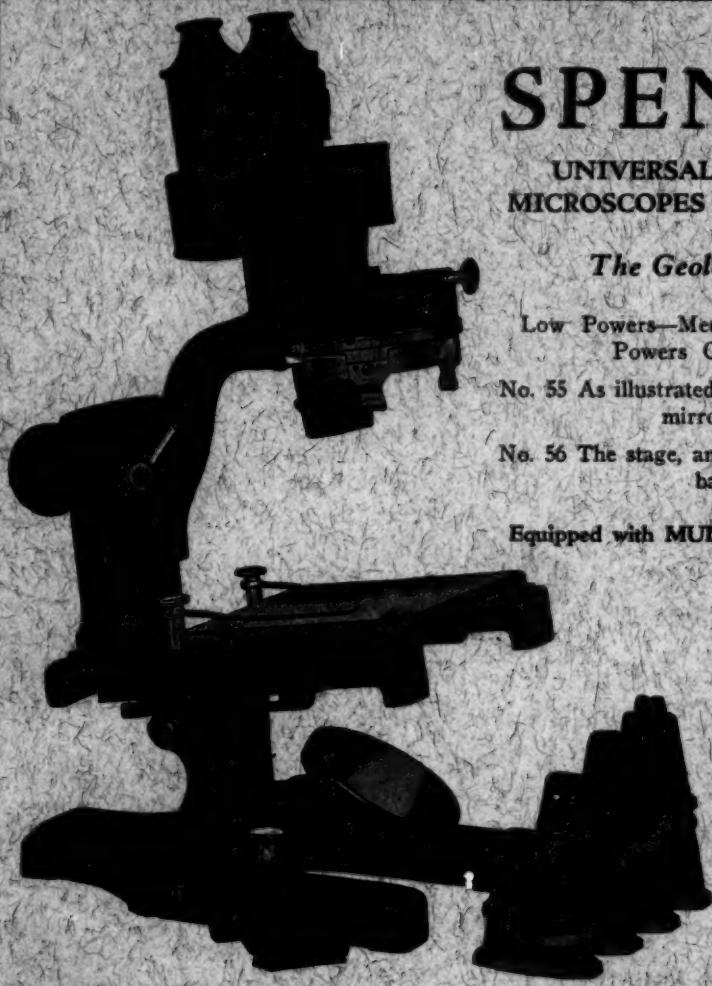

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